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Effects of intermittent fasting on body composition, clinical health markers and memory status in the adult population: a single-blind randomised controlled trial

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Abstract

Introduction Despite the popularity and potential protective effects of intermittent fasting (IF) against metabolic disorders, more human trials must be conducted to highlight its effects on human health. Therefore, the present trial aimed to investigate the effect of IF on the body composition, health markers, and memory status of obese and overweight adults.

Methods A parallel randomised controlled trial was conducted in Lahore, Pakistan, with 30 participants recruited from each of the three arms (regular diet, customised diet, and IF group) with a follow-up period of 12 weeks.

Results There was no significant difference in the mean percentage change in BMI at the end of the study period ($p=0.55$). The IF group exhibited a negative median change (-4.41%) in systolic blood pressure compared with the other two groups ($p=0.014$), with no difference among the groups in diastolic blood pressure or blood sugar levels ($p>0.05$). The percentage change in waist circumference was more significant in the IF group than in the control group, with a significant improvement in the median percentage change in total cholesterol, LDL, triglyceride, and HDL levels ($p<0.05$) as well as in the memory score ($p<0.05$).

Conclusion This study revealed that IF helps improve participants' lipid parameters, systolic blood pressure, and memory status.

Trial Registration The present study is registered at the registry of Clinicaltrials.gov with identity number NCT05521945 and registration date 30/08/22.

Keywords Fasting, Randomized controlled trial, Weight loss diets, Blood sugar, Body composition

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Background

Despite ongoing attempts to reduce obesity, the incidence of this condition is still disturbing in many parts of the world [1]. Statistics reveal that more than one billion people will be overweight worldwide, with an additional 167 million being overweight or obese by the year 2025 [2]. Obesity is often linked with disturbed and excessive eating patterns, specifically when combined with sedentary lifestyle [3]. Numerous studies have evaluated the effects of different techniques in alleviating this complication. However, in the past few years, there has been increasing interest in intermittent fasting (IF) to address obesity and overweight [4]. IF is a popular strategy for weight loss and appears to be a promising primary care intervention for obesity [5].

There are three standard methods of IF, each of which dictates when an individual consumes food. For instance, whole-day fasting is often known as the 5:2 method [6]. Alternate-day fasting is defined as completely refraining from food or reducing intake to 25% or less of one's regular consumption for 24 h, followed by a day of unrestricted eating [7]. Finally, time-restricted feeding entails fasting for 14–20 h each day, followed by ad libitum eating during the remaining hours [8].Statistics revealed an increasing interest in IF, with a sudden upsurge in the number of people searching for it on the internet since 2018 [9] with each method of IF showing varying levels of success in different populations [10].

Body composition has been a focal point in the study of IF, particularly due to its potential to reduce body fat while preserving lean muscle mass. Research indicates that IF, when compared to continuous caloric restriction, may lead to greater fat loss, particularly in the abdominal region, while minimizing muscle loss [11, 12]. Another study highlight that IF may aid in maintaining body weight and reducing metabolic diseases [13]. These findings suggest that IF could be an effective approach to improving body composition, especially for individuals struggling with obesity or weight-related health issues.

In addition, studies have demonstrated that IF can reduce fasting insulin levels and improve insulin sensitivity, making it a potentially valuable intervention for individuals at risk of metabolic disorders like Type 2 diabetes [14]. Improvements in cholesterol levels, triglycerides, and inflammatory markers have also been reported, which could lower the risk of cardiovascular diseases [15]. However, much of the existing research has focused on specific populations, leaving questions about its broader application in general population.

Emerging evidence also suggests that IF may benefit cognitive function, particularly memory. Animal studies have shown that IF can enhance neuroplasticity, reduce brain inflammation, and protect against neurodegenerative processes [16]. In human studies, IF has been associated with improved memory and cognitive performance, although this area of research is still in its infancy [17].

Despite these promising findings, there is a need for more rigorous, controlled trials to understand the combined effects of IF on body composition, clinical health markers, and memory status in the adult population. Most existing studies have either focused on one of these outcomes or have been conducted on specific subgroups. Therefore, a comprehensive evaluation of these three aspects in overweight and obese adult population will provide valuable insights into the overall efficacy of IF.

This study aims to fill that gap by conducting a single-blind randomized controlled trial to investigate the effects of IF on body composition primarily body mass index, clinical health markers, predominantly lipid profile status, and fasting blood sugar and memory status in obese and overweight adult population. By assessing these outcomes concurrently, this study seeks to offer a more holistic understanding of the potential benefits of IF in promoting both physical and cognitive health.

Methods

Study aims

The present trial aimed to investigate the effect of IF on the body composition, health markers, and memory status among adults.

Study design

A multicentre, three-armed, parallel randomised controlled trial was conducted with an allocation ratio of 1:1:1 to examine the effectiveness of IF in improving the health indicators of overweight and obese, otherwise healthy adults. Participants' blood pressure and anthropometric data (weight, BMI, and waist circumference) were the study's primary endpoints. The secondary endpoints were fasting blood glucose levels and serum lipid profiles. The memory status of the participants was documented as a tertiary endpoint of the study.

Study setting

The present study was conducted in the Lahore district of Punjab, Pakistan. The study location was selected for its suitability for the participants, as statistics indicate a high prevalence of obesity and noncommunicable diseases among the district residents [18].

Participants and sample

People aged 40 to 60 years at the time of enlistment who agreed to participate and had a body mass index (BMI) > 25 were enrolled in the present trial from the corporate sector. This age limit was chosen because of the increased vulnerability to health issues related to short-term memory, blood pressure, blood sugar, and increased

cholesterol levels [18, 19]. However, participants who were taking any statin medication, were terminally ill, had cancer, were pregnant or were taking anti-diabetic medicines were excluded from the present study.

A sample of 30 participants was calculated for each arm, with 80% power of the study, using 34.01±6.48 as mean post HDL in control group and 38.62±6.45 in intermittent group at 95% confidence interval (CI) using the formula given below [13].

$$n = \frac{\{(\delta_1^2 + \delta_2^2) \times (Z_{1-\alpha/2} + Z_{1-\beta})^2\}}{|\mu_2 - \mu_1|^2}$$

Trial groups and interventions

The participants were randomised into three groups, i.e., the control group, intervention group A and intervention group B. All the participants in the three groups were recruited for 12 weeks in the trial, and the following interventions were provided to each group.

Control group

No intervention was given to the participants recruited to the control group, and they were kept on a regular normal diet (ND). Members in the control group were encouraged not to change their eating regimen or their usual lifestyle during the trial period.

Intervention group A- IF

The participants recruited to intervention group A were kept on IF. The intervention IF group was given specific instructions to fast for approximately 16 h seven days a week, from 9 pm to 1 pm. They were urged to return to their regular dietary plan during 8 h of non-fasting intervals, i.e., 1 pm to 9 pm, with few instructions.

Specific instructions for the IF group

Fasting period (16 h)

During the 16-hour fasting window, participants were advised to stay adequately hydrated with simple water, black coffee, black tea, or lemonade water with some fibre twice a day and to avoid carbonated and sugary beverages altogether.

Eating window (8 h)

During the 8 h of the eating window, participants were advised to break their 16-hour fast with a mixture of basil and chia seeds water, cumin water or honey and lime water. Furthermore, the participants were advised to use lentil soup and to replace simple carbohydrates with complex carbohydrates.

Intervention group B- customised diet (CD) plan

The participants recruited to intervention group B were kept on CD plans based on their BMI, which a certified dietician determined. For the CD group, after their BMI was taken and their caloric intake was assessed via 24-hour dietary recall, a simple CD primarily based on carbohydrate, protein and fat intake was prepared for them that could be quickly followed.

Randomisation and blinding

A statistician, independent of the study, created a random allocation sequence on a Microsoft Excel spreadsheet. Consecutive numbers were assigned to three arms. There were no restrictions (e.g., definition, block size). Two dietitians and one trained research nurse recruited participants and assigned them sequential ID numbers based on the grouping in which they were placed. The present trial was based on a single-blind methodology where only the investigator was blinded to the allocation.

Data collection and laboratory methods

At baseline, sociodemographic characteristics (age, sex, occupation) and physical activity were recorded using a structured questionnaire with a shortened version of the International Physical Activity Questionnaire (IPAQ) [20]. However, data related to anthropometric indices, blood parameters and memory status were collected at baseline and at the end of the trial. For anthropometric measurements and blood samples, participants were directed to the Government Teaching Hospital, i.e., Jinnah Hospital, where trained paramedic staff performed clinical assessments of participants at the hospital and recorded heart rate and blood pressure readings, both systolic and diastolic pressures, using a sphygmomanometer.

The staff captured the anthropometric data. BMI was calculated by dividing one's height in meters squared by one's weight in kilograms, while the participants' wrist circumference was measured using a measuring tape when the participants exhaled normally, with the tape placed halfway between the iliac crest's top and bottom edges.

The registered participants were then invited to a designated room in the Jinnah Hospital multidisciplinary laboratory. After each subject had fasted for 12 h, a skilled study nurse drew 5 ml blood samples by venipuncture. A Jinnah Hospital laboratory assistant collected blood to measure the serum cholesterol and blood glucose levels. The full-fasted lipid profile of each subject included total cholesterol, triglyceride, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) levels. Serum lipid and fasting glucose (FBS) concentrations were estimated using a fully automated chemical immunoassay analyser (Abbott Alinity

Ci analyzer). Standard laboratory techniques for assessing participants' low- and high-density lipid profiles were used [21].

To capture individuals' memory status, the Multifactorial Memory Questionnaire (MMQ) was used. The MMQ has three scales i.e., Satisfaction (a measure of worry about memory), Ability (a measure of subjective forgetfulness), and Strategy (a measure of compensatory memory strategies) consisting of 18–20 questions each, with a total of 57 items ranked on a 5-point Likert scale (1=never, 2=rarely, 3=sometimes, 4=often, 5=always) [22]. Improved satisfaction and ability are associated with higher scores on the MMQ subscales. Conversely, a lower score on the strategy scale aligns with the cognitive theory, suggesting that compensatory memory strategies involve techniques or modifications in behaviour or the environment to address deficits, weaknesses, injuries, or perceived inadequacies in a specific area or skill. A higher score on the strategy scale indicates a greater reported frequency of using memory aids and strategies compared to lower scores. The negative correlation between the strategy scale and Satisfaction and Ability implies that individuals with lower satisfaction and self-appraisal of memory are inclined to employ more memory strategies [23].

Follow-up and compliance

All the participants recruited from the three arms were followed for 12 weeks. Compliance was thoroughly monitored using a combination of weekly phone calls and messages throughout the trial duration. Participants were encouraged to visit the Jinnah Hospital outpatient department and given a dedicated contact number for a doctor or nutritionist in case of emergencies or any concerns. Treatment was free of charge for trial participants during the study period. After the follow-up of 12 weeks, anthropometric assessments and memory status assessments were performed by the study dietician and research nurse. A follow-up 5-mL blood sample was also taken from all participants who had completed the study for fasting blood sugar and serum cholesterol.

Ethical consideration and registration

The Departmental Doctoral Program Committee (DDPC) of the University of the Punjab, Lahore, approved the study (Letter No: D/119/ISCS), with the study registered at the registry of Clinicaltrials.gov with identity number NCT05521945. The present study was completed during a course of 1 year with the study registered on 30/08/22 and the follow-up of last participant completed on 11/08/23. The study was also carried out according to the Declaration of Helsinki.

Statistical analysis

IBM SPSS Statistics version 20 was used to analyse the data. The descriptive statistics of the qualitative variables are presented as the frequency (f) and percentage (%), while those of the quantitative variables are given as the mean standard deviation (SD) for normally distributed variables and the median±interquartile range (IQR) for skewed variables. Furthermore, for inferential statistics, paired sample t-tests and Wilcoxon signed rank tests for normally distributed and skewed distributions, respectively, were used to assess the difference in the time component (pre- and post-comparison) for all three groups. For analysing the differences among groups (ND, CD and IF), analysis of variance (ANOVA) and the Kruskal–Wallis test were applied. Finally, to analyse the differences in categorical variables among the three study groups, the chi-square test was applied. All the tests were applied at a 95% CI, with <0.05 indicating statistical significance.

Results

Participant recruitment

Figure 1 shows the CONSORT flowchart. A total of 106 participants were approached, 102 of whom were evaluated for qualification. 12 were excluded (four declined to fast, four failed to adhere to a CD, and four failed to contact on assessment day), and 90 were randomized into one of the three arms of the study for a duration. All 90 participants were included in the data analysis, as none of them were lost to follow-up.

Baseline characteristics and primary outcomes

Overall, the majority of the participants in all three arms were male (60.0% in the control group; 63.3% in the CD and IF groups), with median ages of 48.50±9.0, 50.0±10.25 and 48.0±11.25 years for the control, customized and IF groups, respectively. The results showed that there was no significant difference among the three groups in terms of age or sex distribution (p value>0.05). The majority of the participants recruited to the control group had a low level of physical activity (66.7%), with 42.5±108 serving as the median minutes of activity/week. However, 23.3% and 46.7% of the participants in the CD group and IF group had low levels of physical activity, respectively. The median minutes of activity per week for the CD group were 160.0±191.0, while those for the IF group were 67.50±150. The CD group had the highest median for total activity minutes per week, followed by the IF group, with a significant difference in physical activity among the groups (160.0±191.0 vs. 67.50±150.0, $p=0.001$) (Table 1).

Furthermore, there was no significant difference between the three intervention arms in terms of the mean percentage change in BMI at the end of the study period (ΔBMI%, control arm=0.47±1.08,

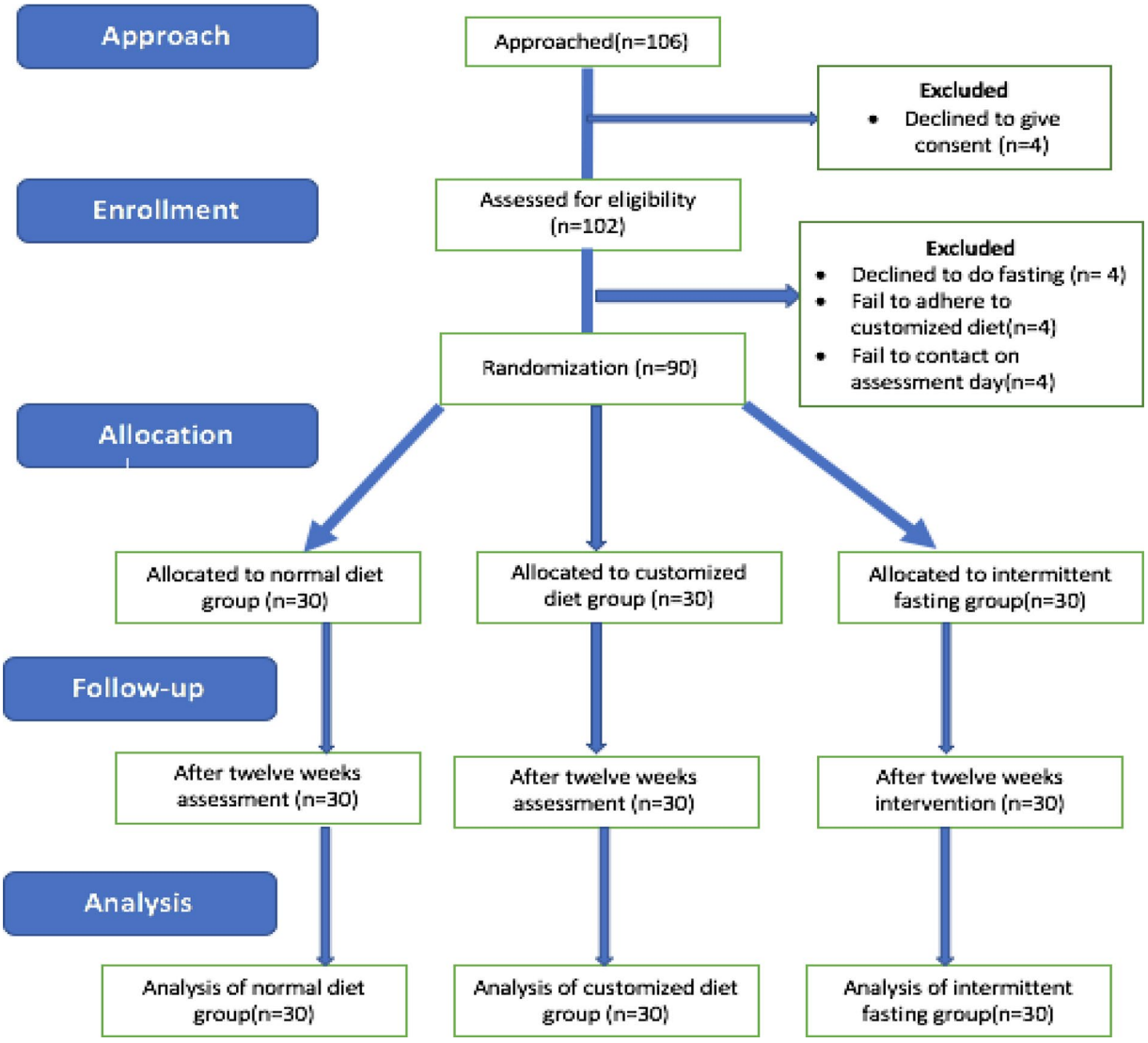

Fig. 1 Consort flow-diagram

CD=1.25±2.39, IF=10.04±4.15, $p=0.55$). However, for systolic blood pressure (SBP), the IF group had a significant negative median percentage change (-4.41%) compared with the other two groups (control arm=0.0±4.14, CD=0.00±5.34, IF=-4.41±9.81, $p=0.014$). For diastolic blood pressure (DBP) and the percentage change in blood glucose level, there was no significant difference among the three groups ($p>0.05$). For the percentage change in waist circumference, significant results were observed among the groups in the IF group, in which the change was the greatest (3.60±2.50; <0.001) compared to that in the control (0.00±0.82) and CD (0.00±0.62) arms (Table 1).

Secondary outcomes

In terms of various lipid parameters, there was no significant difference among the three groups in preintervention blood samples (serum total cholesterol p value=0.522; serum triglyceride p value=0.522; serum HDL p value=0.339; cholesterol LDL p value=0.305). However, after the interventions, there were significant differences in the serum total cholesterol level ($p<0.05$), serum triglyceride level ($p<0.05$), and serum HDL level ($p<0.05$) among the three intervention groups, whereas no difference was observed in the LDL cholesterol level among the three intervention groups ($p=0.305$).

In addition, the analysis further revealed significant changes in the serum total cholesterol level ($p<0.001$), serum triglyceride level ($p<0.001$), serum high-density lipoprotein cholesterol (HDL) ($p<0.005$), and serum cholesterol LDL ($p<0.001$) before and after intervention in the IF group, whereas no differences were observed in the serum total cholesterol level, serum triglyceride level,

Table 1 Comparison of demographic variables, physical activity, changes in fasting blood sugar (BS) levels, systolic blood pressure (SBP) and diastolic blood pressure (DBP), body mass index (BMI) and waist circumference among the different groups ($n=90$)

		ND($n=30$)	CD($n=30$)	IF($n=30$)	Test value	*p* value
Age (years)	*Median ± IQR*	48.50 ± 9.0	50.0 ± 10.25	48.0 ± 11.25	0.971[b]	0.615
Gender	*Male*	18(60.0%)	19(63.3%)	19(63.3%)	0.095[c]	0.954
	Female	12(40.0%)	11(36.7%)	11(36.7%)		
Physical activity	*Low*	20(66.7%)	7(23.3%)	14(46.7%)	15.57[c]	0.004*
	Moderate	6(20.0%)	9(30.0%)	11(36.7%)		
	High	4(13.3%)	14(46.7%)	5(16.7%)		
Total days of activity	*Median ± IQR*	3.50 ± 7	7.0 ± 9.0	5.50 ± 5.0	14.68[b]	0.001**
Total activity min/week		42.5 ± 108	160.0 ± 191.0	67.50 ± 150	16.65[b]	< 0.001**
Prefasting BS	*Mean ± S. D*	113.47 ± 16.34	102.20 ± 16.23	97.97 ± 11.78	18.656[b]	< 0.001**
Postfast BS		106.63 ± 17.06	98.27 ± 16.22	95.17 ± 9.74	10.39[b]	0.006*
%Δ BS	*Median(IQR)*	4.28 ± 11.14	1.0 ± 16.90	2.22 ± 9.64	1.099[a]	0.338
Pre-SBP	*Median(IQR)*	120.0 ± 11.50	110.0 ± 10.0	110.0 ± 18.50	5.969[b]	0.051
Post-SBP		120.0 ± 3.50	110.0 ± 15.75	111.0 ± 10.0	11.182[b]	0.004*
SBP(% Δ)		0.0 ± 4.14	0.00 ± 5.34	-4.41 ± 9.81	8.516[b]	0.014*
Pre- DBP	*Median(IQR)*	80.0 ± 10.0	80.0 ± 2.0	80.0 ± 10.0	2.315[b]	0.314
Post-DBP		84.0 ± 10.0	86.0 ± 10.0	86.0 ± 7.25	2.289[b]	0.318
DBP(%Δ)		0.00 ± 6.87	0.00 ± 9.76	-1.81 ± 19.45	0.871[b]	0.647
pre-BMI	*Mean ± S.D*	31.04 ± 4.68	27.15 ± 5.68	29.95 ± 3.47	5.462[b]	0.006*
post-BMI		30.90 ± 20.60	26.75 ± 5.35	26.93 ± 3.29	8.035[b]	0.001*
BMI (%Δ)		0.47 ± 1.08	1.25 ± 2.39	10.04 ± 4.15	0.604[a]	0.549
Pre-Waist circumference	*Median(IQR)*	79.0 ± 8.25	57.32 ± 31.52	80.0 ± 11.0	0.554[b]	0.75
Post-Waist circumference		78.60 ± 10.0	80.0 ± 11.14	77.80 ± 10.60	0.940[b]	0.625
waist circumference%Δ		0.00 ± 0.82	0.00 ± 0.62	3.60 ± 2.50	44.63[b]	< 0.001**

a| Analysis of variance; **b|** Kruskal–Wallis test; **c|** chi-square test; **d|** Wilcoxon signed rank test; **e|** paired sample t test; **highly significant; *significant

The activity level is low. MODERATION, if not moderate or vigorous: (a) at least 20 min of vigorous activity every day for three days or more; (b) at least 30 min of walking every day or five days of moderate activity; or (c) five days or more of walking, activities of moderate or vigorous intensity, or both, with a minimum T = total physical activity of at least 600 MET-minutes per week. HIGH (a) Vigorous-intensity activity on no less than 3 days (at least 20 min, accomplishing a minimum total physical activity such as 1500 MET-minutes/week) OR (b) at least 7 days of any combination of walking, moderate-intensity, or vigorous-intensity activities accomplishing a minimum total physical activity of no less than 3000 MET-minutes/week

serum HDL level, or cholesterol LDL level before or after intervention in the ND or CD group (Table 2).

Tertiary outcome

With respect to the tertiary outcome, the results revealed significant differences in satisfaction ($p=0.01$), ability ($p<0.001$) and strategy score ($p<0.001$) among the three intervention groups. Similarly, the postintervention results also showed a significant difference in satisfaction scores among the three groups ($p<0.001$), with the IF group showing the highest satisfaction score. In addition, the intragroup analysis revealed a significant increase in the satisfaction score in the IF group (40.0 ± 13.0 vs. 50.6 ± 8.0; $p<0.001$).

For ability score, the intragroup analysis revealed a significant increase for all three study groups, i.e., ND ($p=0.001$), CD ($p=0.001$) and IF ($p<0.001$). However, the greatest difference was observed among the IF group pre- and postintervention (test value=-4.78; $p<0.001$), with a significant difference across the three study groups postintervention ($p<0.001$).

Finally, for strategy, there was a significant difference between the scores across the three study groups, preintervention ($p<0.05$) and postintervention ($p<0.001$), with the IF group showing the lowest score for strategy postintervention in comparison to the ND and CD groups (30.0 ± 20 vs. 56 ± 31 and 40.50 ± 24). In addition, the analysis revealed a significant reduction in the strategy score before and after intervention in the IF group ($p<0.001$), with a median change of -23.07 ± 14.45. A significant difference was also observed for the strategy score for the CD group ($p<0.05$); however, the score increased from postintervention in the comparison group to preintervention (Wilcoxon Test Value z= -2.47) (Table 3).

Adverse events

No actual or suspected adverse reactions occurred during the trial. Only two participants in the IF group reported light-headedness, which resolved when they hydrated themselves during the fasting period.

Table 2 Comparisons of total serum cholesterol levels, serum high-density lipoprotein cholesterol (HDL) levels, low-density lipoproteins (LDL) levels, and total cholesterol levels in different study groups

			ND($n=30$)	CD($n=30$)	IF($n=30$)	Test value	*p* value
Serum total cholesterol level	Pre	*Mean ± S.D*	185.90 ± 43.38	181.90 ± 39.58	175.17 ± 30.57	1.30[a]	0.522
	Post		196.90 ± 42.31	177.97 ± 35.97	159.77 ± 26.36	6.137[a]	0.046*
	Pre–post	Test value	-1.836 [e]	− 0.730 [e]	-4.350[e]		
		p value	0.066	0.465	< 0.001**		
	%Δ	*Median (IQR)*	0.00 ± 3.16	0.00 ± 0.00	3.17 ± 12.50	37.808[b]	< 0.001*
Serum triglyceride level	Pre	*Median(IQR)*	167.50 ± 110	147.50 ± 102	153.50 ± 95	1.30[b]	0.522
	Post		189 ± 142	141.50 ± 88	146.00 ± 64	6.14[b]	0.024*
	Pre–post	Test value	-0.533[d]	-1.214[d]	-3.601[d]		
		p value	0.594	0.225	< 0.001**		
	%Δ	*Median(IQR)*	0 ± 0	0 ± 0	3.68 ± 21.58	22.22[b]	< 0.001**
Serum HDL	Pre	*Median (IQR)*	34.50 ± 13.25	40.50 ± 14.50	42.0 ± 11.25	1.11[b]	0.339
	Post		36.0 ± 14.25	39.50 ± 15	44.50 ± 8.25	3.14[b]	0.0408*
	Pre-post	Test value	-0.475[d]	-1.461[d]	-3.295[d]		
		p value	0.635	0.144	0.001**		
	% Δ	*Median(IQR)*	0 ± 0	0 ± 0	-6.82 ± 11.11	21.17[b]	< 0.001**
Cholesterol LDL	Pre	*Mean ± S.D*	128.40 ± 47.60	124.23 ± 40.06	115.23 ± 27.27	2.378[a]	0.305
	Post		138.90 ± 47.91	121.17 ± 37.31	105.33 ± 24.19	5.702[a]	0.05
	Pre-post	Test value	-1.960[e]	< 0.001[e]	-3.747[e]		
		p value	0.050	1.000	< 0.001**		
	% Δ	*Median (IQR)*	0.00 ± 1.26	0.00 ± 0.00	3.77 ± 13.34	40.258[b]	< 0.001**

a| Analysis of variance; **b** |Kruskal–Wallis; **c|** chi-square test; **d|** Wilcoxon signed rank test; **e|** paired sample t test; **highly significant; *significant

Table 3 Comparison of memory status (satisfaction, ability and strategy score) among different study groups

			ND	CD	IF	Test value	*p* value
Satisfaction score	Pre	*Median (IQR)*	27 ± 16	39.50 ± 23	40.0 ± 13.0	9.24[b]	0.01*
	Post		27 ± 17	42 ± 22	50.6 ± 8.0	25.7[b]	< 0.001**
	Pre-post	Test value	-7.52[d]	-4.51[d]	-4.3[d]		
		p value	0.452	< 0.001**	< 0.001**		
	%Δ	*Median(IQR)*	0 ± 3.38	7.85 ± 8.05	20.58 ± 29.43	59.02[b]	< 0.001**
Ability score	Pre	*Median(IQR)*	23.50 ± 24	46.50 ± 33	50 ± 14	17.34[b]	< 0.001**
	Post		25 ± 26	47.50 ± 32	65.50 ± 10	35.19[b]	< 0.001**
	Pre-post	Test value	-3.24[d]	-3.46[d]	-4.78[d]		
		p value	0.001**	0.001**	< 0.001**		
	%Δ	*Median(IQR)*	0 ± 8.08	1.56 ± 6.06	25.65 ± 18.46	52.67[b]	< 0.001**
Strategy score	Pre	*Median(IQR)*	55 ± 30	40.50 ± 23	40.50 ± 24	7.47[b]	0.024*
	Post		56 ± 31	40.50 ± 24	30.0 ± 20	16.76[b]	< 0.001**
	Pre-post	Test value	-1.09[d]	-2.47[d]	-4.78[d]		
		p value	0.274	0.014*	< 0.001**		
	%Δ	*Median(IQR)*	0 ± 2.14	1.59 ± 4.32	-23.07 ± 14.45	56.89[b]	< 0.001**

a Analysis of variance; **b** |Kruskal–Wallis; **c|** Chi-square; **d|** Wilcoxon signed rank test; **e** |Paired sample t-test; **Highly significant; *Significant

Discussion

The findings of the present study showed that IF can reduce body weight and waist circumference while also improving lipid profiles. The beneficial effects of various forms of IF, such as Ramadan fasting and alternate-day fasting, on body weight and cholesterol levels are consistent with the findings of previous studies [11–13, 15, 24]. However, no significant difference in terms of mean percentage change in BMI was observed in the present study between CD, IF and control group. The study findings also revealed a significant role of IF in reducing the SBP bas compared to other study groups, whereas no significant difference was found for DBP among the three study groups. These findings echo with the literature based on animal studies, that indicate the role of IF in altering the makeup of the gut microbiota, plasma metabolome and cecal and restricting the development of hypertension [25]. Likewise, the findings of the previous human trials also highlight the beneficial effects of IF in reducing the SBP among prediabetic men [14].

Notably, the findings of the present study showed that IF had a considerably positive influence on memory

satisfaction, memory ability, memory strategy and serum lipid profiles, with a significant increase in HDL cholesterol and a decrease in LDL and total cholesterol. Our study suggested that IF may have memory and lipid profile benefits. The CD showed some help but was not as pronounced as the IF, while the ND showed only moderate alterations. However, it is essential to note that the memory strategy scores of the IF group decreased significantly, implying potential cognitive trade-offs. Little evidence from literature also highlights the improved memory status and cognitive abilities associated with IF [17]. These findings highlight the promise of IF as a nutritional method for improving memory and lipid profiles, but further research into its use in other cognitive techniques is needed.

With regard to the role of IF on lipid profile, it has been determined that various forms of IF can lead to an increase in HDL cholesterol levels of 1–14 mg/dl, a decrease in LDL cholesterol levels of 1–47 mg/dl, a reduction in total cholesterol levels of 5–88 mg/dl, and a decrease in triglyceride levels of 3–64 mg/dl [26]. However, compared to other kinds of IF, our approach is safe and successful and smoothly integrates into normal life without adding any financial or physical strain. Individuals can include IF in their habits without spending time preparing low-calorie meals. Maintaining a 12-hour fasting window is possible with an early breakfast and a timely dinner, which may be performed on weekdays and weekends. Be that as it may, it might challenge people who work late or have a functioning public activity, including continuous eating out. According to numerous animal studies, IF may help with ischaemic stroke, Parkinson's disease, autism spectrum disorders, mood and anxiety disorders, and Parkinson's disease [24, 27]. A study conducted in mice revealed that long-term memory retention and the number of neuroblasts were enhanced more by IF than by other dietary protocols [28]. Although fasting was common in the past, the focus of late cell research has been on the potential benefits to the brain that can be actually shown. Perhaps there is a promising, multi-focused, self-controlled, and cost-free treatment available in the universe of expensive medical services for neurological issues [29]. Similarly, our study explored memory status and found statistical significance (p value < 0.000).

Previous research has shown that IF intervals ranging from 12 to 36 h cause a metabolic shift [17]. This transition causes triglycerides to be broken down into fatty acids and glycerol, after which these fatty acids are converted into ketone bodies within the liver [3]. During fasting, cells and tissues derive energy from fatty acids and ketone bodies [30]. Liver subatomic alterations advance the outflow of PPARa and PGC-1a. This boosts fatty acid oxidation and apo A synthesis, producing higher HDL levels. Furthermore, this procedure lowers apo B levels, decreasing hepatic triglyceride and LDL levels [24, 31]. Shibata and associates concentrated on the sterol administrative component restricting protein 2 (SREBP-2) in mice. Their findings demonstrated that irregular fasting can diminish cholesterol levels through SREBP-2 regulation [32].

The present study is one of its kind as it comprehensively evaluates the combined effects of IF on body composition, clinical health markers, and memory status in the adult population. However, there are certain limitations of the presents study. Firstly, the sample size was too small to be generalized to the whole population, and the follow-up time was insufficient to observe effects on a larger population. Additionally, there was a lack of funding to conduct additional laboratory tests, which is why no invasive tests were performed to assess the memory status of the participants. Lastly, data related to detailed macronutrient and calorie values of the participants was not collected that could provide useful insights to fully understand the impact of dietary interventions and outcome. Future studies aimed to include detailed macronutrient and calorie analyses to enhance the robustness and replicability of the findings should be conducted. Further, on the basis of the limitations of the present study, future trials with longer follow-up periods and larger sample size are recommended. Furthermore, the use of the Dexcom G6 and Abbott Freestyle Libre sensors for biometric data assessment and the provision of an end-to-end remote patient monitoring programme are recommended. Another recommendation is to assess immunoassay parameters to strengthen the study.

Conclusion

The present study concluded that IF is an effective strategy to maintain the body composition, clinical health markers and memory status of adult individuals in terms of their weight, BMI, waist circumference, lipid profile, and satisfaction, ability and strategy score. However, to investigate these promising results, additional trials in various settings requiring longer follow-up periods are needed.

Abbreviations

IF	Intermittent Fasting
LDL	Low Density Lipoprotein
HDL	High Density Lipoprotein
BMI	Body Mass Index
CI	Confidence Interval
ND	Normal Diet
CD	Customized Diet
ID	Identity
IPAQ	International Physical Activity Questionnaire
FBS	Fasting Blood Sugar
MMQ	Multifactorial Memory Questionnaire
DDPC	Departmental Doctoral Program Committee
f	Frequency
IQR	Interquartile Range

ANNOVA	Analysis Of Variance
CONSORT	Consolidated Standards of Reporting Trials
DBP	Diastolic Blood Pressure
SBP	Systolic Blood Pressure
S.D	Standard Deviation
SREBP-2	Sterol regulatory element-binding proteins
PPARa	Protein Peroxisome Proliferator Activated Receptor Alpha
PGC-1a	Peroxisome proliferator-activated receptor-gamma coactivator

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Author contributions
ZAR: Conceptualization; Data curation; Methodology; Formal Analysis; Software; Visualization; Writing-original draftJS: Conceptualization; Methodology; Visualization; Supervision; Writing-review & editingIZ: Conceptualization; Methodology; Visualization; Supervision; Writing-review & editingRS: Conceptualization; Methodology; Formal Analysis; Software; Writing-review & editingJAK: Methodology; Formal Analysis; Software; Writing-original draftJF: Conceptualization; Methodology; Writing-original draftGJB: Methodology; Data curation; Writing-original draftGA: Methodology; Supervision; Writing-review & editingM.J: Methodology; Supervision; Writing-review & editingAll the authors collaborated on the article and gave their approval for the final submitted version.

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Data availability
The authors will make the raw information supporting the conclusions of this article available without reservation.

Declarations

Ethics approval and consent to participate
The Punjab University Ethical Review Committee reviewed and approved the present study (Letter No: D/119/ISCS). Prior to their participation in the study, each participant provided written informed consent.

Consent for publication
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Competing interests
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