Nutrition 59 (2019) 69–76

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Christian Orthodox fasting in practice: A comparative evaluation between Greek Orthodox general population fasters and Athonian monks

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ARTICLE INFO

Article History:
Received 25 May 2018
Received in revised form 7 July 2018
Accepted 17 July 2018

Keywords:
Christian Orthodox fasting
Mediterranean diet
Nutrient intake
Cardiometabolic markers
Calcium homeostasis
Lipids

ABSTRACT

Objectives: Christian Orthodox fasting (COF), a periodical vegetarian subset of the Mediterranean diet, has been proven to exert beneficial effects on human health. Athonian fasting is a pescetarian COF variation, where red meat is strictly restricted throughout the year. Previous studies have examined the COF nutritional synthesis and health effects in general population fasters (GF) and Athonian monks (AM), separately. The aim of this study is to comparatively evaluate the characteristics and effects of this nutritional advocacy between the two populations.
Methods: The study included 43 male GFs (20–45 y of age) and 57 age-matched male AMs following COF. Dietary intake data were collected in both groups during a restrictive (RD) and a nonrestrictive (NRD) day. Nutritional, cardiometabolic, and anthropometric parameters were compared between the two cohorts.
Results: AM presented lower daily total caloric intake for both RD (1362.42 ± 84.52 versus 1575.47 ± 285.96 kcal, $P < 0.001$) and NRD (1571.55 ± 81.07 versus 2137.80 ± 470.84 kcal, $P < 0.001$) than GF.They also demonstrated lower body mass index (23.77 ± 3.91 versus 28.92 ± 4.50 kg/m^2, $P < 0.001$), body fat mass (14.57 ± 8.98 versus 24.61 ± 11.18 kg, $P = 0.001$), and homeostatic model assessment for insulin resistance values (0.98 ± 0.72 versus 2.67 ± 2.19 mmol/L, $P < .001$) than GF. Secondary hyperparathyroidism (parathyroid hormone concentrations: 116.08 ± 49.74 pg/mL), as a result of profound hypovitaminosis D [25(OH)D: 9.27 ± 5.81 ng/mL], was evident in the AM group.
Conclusions: The results of the present study highlight the unique characteristics of Athonian fasting and its value as a health-promoting diet. The effects of limitation of specific vitamins and minerals during fasting warrants further investigation.

Introduction

Previous research [1–4], has indicated that the Mediterranean diet (MD) is an ideal dietary paradigm for the prevention of cardiovascular and degenerative diseases [5–9]. Several studies [10–14] attested emerging roles for a subset of the MD, the Greek Orthodox fasting ritual, which for religious reasons is considered to be deeply integrated in the dietary behavior of the Greek population [11–13].

Christian Orthodox fasting (COF) is adopted as the predominant, traditional dietary pattern for a large part of the Greek Orthodox

S.N.K. conceptualized and designed the study, collected all data, and drafted the first version of the manuscript. S.N.K., T.K., A.P., D.F., D.S., H.M., and K.K. analyzed and interpreted the dietary data. S.N.K., T.K., H.M., P.Z., and D.P.N. interpreted biochemical results. M.K. conducted biochemical analysis of the samples. A.P. and D.F. performed the literature review and the statistical analysis. All authors have read and critically revised the manuscript and approved the final version. The authors have no conflicts of interest to declare.

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https://doi.org/10.1016/j.nut.2018.07.003
0899-9007/

population for prolonged periods (from 120 to 180 d) annually [8]. It has been suggested that COF shares the beneficial effects of the typical MD by promoting specific cardioprotective mechanisms, including reduced intake of dietary cholesterol and fatty acids, and optimal effects on plasma lipid concentrations [15]. It typically integrates parameters of dietary restriction of specific macronutrients, given that it suggests abstinence from meat, dairy products, and eggs daily, and from fish and olive oil on specific weekdays, during fasting periods [8]. In addition, most existing data [11–16] indicate that restricted calorie intake is evident during COF periods, accentuating COF as a unique component of both caloric and dietary restriction regimens, among the other well-investigated religiously motivated dietary models [10,11].

A considerable number of previous studies [8,11–16] have focused on the nutritional aspects of COF as practiced by the general Orthodox population, reporting interesting data on this obscured but still vital subtype of the MD. This dietary pattern, inducted by the Greek Orthodox Church as a way of spiritual prosperity for the faithful [8], was initially followed by the Greek Orthodox monks, comprising the main nutritional model of the monasterial community of Mount Athos. The autonomous monasterial state of Mount Athos located in Halkidiki, northern Greece, is the largest Greek monasterial community and a major center of Eastern Orthodox monasticism [11]. A population of ~1800 male monks reside in 20 different monasteries, incorporating strict dietary and physical activity daily plans into their religious duties. Athonian COF can be described as a pescetarian variation of the typical COF, meaning that red meat consumption is totally restricted throughout the year, during both fasting and nonfasting periods.

The present study attempted to comparatively evaluate COF, as practiced by two distinct populations: the Orthodox monks in Mount Athos, who strictly adhere to fasting, and a cohort of general population in central northern Greece, who practice fasting rituals from early adulthood as periodical fasters, with a discourse on the similarities and differences in practicing COF between the two cohorts and the comparative evaluation of the nutritional synthesis in each cohort according to recommended dietary intakes suggested by international health organizations in the context of a health-promoting diet.

Methods

Study population

Study recruitment included 43 Christian orthodox male adults (group 1), 20 to 45 y of age, residing in the region of Chalkidiki, northern Greece and an age-matched cohort of 57 Orthodox male Athonian monks (AM), from the monasterial community of Mount Athos (group 2). Individuals with ≥6 mo of adherence to COF were included in the study. Individuals with chronic diseases and those receiving medication or vitamin or mineral supplements were excluded. Inclusion and exclusion criteria for the recruitment of participants in the present study were previously described in detail [11].

Study design

Dietary analysis

Dietary intakes were analyzed during 2 d of COF: 1 d during a weekend of Nativity Fast, during which fish, olive oil, cereals, legumes, nuts, vegetables, fruits, and alcohol are allowed, defined as a *nonrestrictive day* (NRD), and a weekday during Great Lent, during which olive oil and fish are additionally excluded from the regular nutritional plan, defined as a *restrictive day* (RD). We followed this categorization for both study groups, as previously reported [11].

Consumption of food and beverages was self-recorded by the participants using a 24-h dietary recall and subsequently confirmed by a dietitian. The accuracy of estimation of portion sizes was based on standardized photo albums [17–19]. The protocol followed for the dietary analysis was previously described [11] and was based on data derived from the Food Processor Nutrition Analysis Reports software, adhering to US dietary guidelines [20], the Hellenic Health Foundation [21], and the US Recommended Dietary Allowance (RDA)/Recommended Daily Intake (DRI) values [22]. Percentage total energy intake (%TEI) was calculated using conversion factors of 4, 4 and 9 kcals/g, respectively for carbohydrates, protein, and fat [23].

Anthropometric measurements and biochemical analysis

Anthropometric measurements and biochemical analyses were performed in both groups using standardized procedures. Exact methods, reference ranges, equipment used, and other details were previously analytically described [11]. In brief, body weight (BW) was recorded to the nearest 0.01 kg using a calibrated computerized digital balance (K-Tron P1-SR, Onrion LLC, Bergenfield, NJ, USA); each participant was barefoot and lightly dressed during measurement. The body mass index (BMI) was calculated as the ratio of weight in kilograms divided by the height in meters squared (kg/m^2) [24]. Body fat (BF) mass and percentage, visceral fat (VF), muscle mass, fat-free mass, and total body water were measured using bioelectrical impedance analysis (SC-330 S, Tanita Corporation, Tokyo) [25]. Insulin resistance was calculated using the homeostasis model assessment (HOMA-IR) formula described by Matthews et al. [26] as follows: FPI (μU/mL) × FPG (mmol/L)/22.5, where FPI stands for fasting plasma insulin and FPG for fasting plasma glucose.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki on the human trial performance. Written informed consent for inclusion in the study was given by participants. Official written approval for the inclusion of the AM group was given by the Holy Supervision Council composed of representatives from all 20 monasteries of Mount Athos, after submission of the full study protocol 12 mo before study initiation.

Statistical analysis

Paired samples *t* test was used to compare dietary and nutrient intake on RD and NRD. Dietary and nutrient intake on RD and NRD between groups (lay people sample versus monks) was compared using independent sample *t* test. Comparing dietary intake as percentages were calculated using Mann–Whitney U test for between-group analyses, and Wilcoxon signed-rank test for within-group analyses. For ease of interpretation and facilitating meta-analysis in the future, group statistics are reported as means and SDs, even when nonparametric statistics were used to test for statistical significance between the two groups. Following the recommended reporting guidelines for medical and behavioral research [27], means and SDs were provided for all comparisons and respective effect sizes (Cohen's *d*) were reported for all statistical tests. Effect sizes were discussed in both theoretical and practical implications according to the recommended reference values [28,29]. Level of significance was defined as $P < 0.05$ (nondirectional) for all statistical tests. Data analyses were performed using SPSS version 25 (IBM, Armonk, NY, USA). Effect sizes were calculated using the online meta-analysis effect-size calculators [30,31], with Morris and De Shon's correction (Eq8) for paired-sample comparison [32].

Results

Demographic and anthropometric population characteristics are shown in Table 1. Participants in the GF group (group 1) adhered to COF periodical patterns from early adulthood (mean duration: 19.2 ± 4.5 y).The monks group adhered to religious fasting continually, since the beginning of their monastic life (mean duration: 13.27 ± 8.9 y). Median BMI and percent of BF values in group 1 were above the optimal range (28.92 ± 4.5 kg/m^2 and 26.04 ± 8.18%, respectively). Group 2 demonstrated significantly lower BMI (23.77 ± 3.91 versus 28.92 ± 4.50 kg/m^2, $P < .001$), BF mass (14.57 ± 8.98 versus 24.61 ± 11.18 kg, $P = 0.001$), waist circumference values (83.26 ± 4.23 versus 94.32 ± 3.32 cm, $P < 0.001$), and VF mass (7.08 ± 4.50 versus 13.49 ± 5.87 kg, $P < 0.001$) compared with group 1.

Table 1
Demographic and anthropometric parameters of the two groups

Parameter	Group 1: General population fasters	Group 2: Athonian monks	*P*-value
Sex	Males (n = 43)	Males (n = 57)	–
Age (y)	38.52 ± 11.44	38.82 ± 10.16	0.170
Years at Mt. Athos (y)	–	12.69 ± 8.41	–
Years of monasticism (y)	–	13.27 ± 8.19	–
Weight (kg)	91.27 ± 13.46	74.2 ± 12.35	<0.001
Height (cm)	178.07 ± 6.24	176.69 ± 3.25	0.160
BMI	28.92 ± 4.50	23.77 ± 3.91	<0.001
BF (%)	26.04 ± 8.18	18.33 ± 8.34	<0.001
BF (kg)	24.61 ± 11.18	14.57 ± 8.98	0.001
VF (kg)	13.49 ± 5.87	7.08 ± 4.50	<0.001
WC (cm)	94.32 ± 3.32	83.26 ± 4.23	<0.001
FFM (kg)	66.63 ± 5.50	59.76 ± 6.07	<0.001
MM (kg)	59.38 ± 5.30	33.31 ± 4.54	<0.001
TBW %	54.24 ± 6.01	60.01 ± 6.21	<0.001
TBW kg	48.87 ± 3.99	43.94 ± 4.41	<0.001
BMR kcal	1810.09 ±118.59	1661.88 ± 131.07	<0.001

BF, body fat; BMI, body mass index; BMR, basal metabolic rate; FFM, fat-free mass; MM, muscle mass; TBW, total body water; VF, visceral fat; WC, waist circumference.

Comparison of dietary and nutrient intake on fasting and nonfasting days

Group 1: General population fasters

Table 2 presents macro-t and micronutrient intake on RD and NRD for group 1. A key finding was that daily energy intake was considerably lower on RD than NRD (1575.5 ± 285.96 versus 2137.8 ± 470.84 kcal, respectively; $P < 0.001$). Fat intake was lower during RD than NRD (54.94 ± 26.92 versus 104.59 ± 31.22 g, respectively; $P < 0.001$). Total fat intake (%TEI) differed significantly between RD and NRD (31 ± 13.71% versus 44.58 ± 9.23%, respectively; $P = 0.002$). Protein intake was higher on NRD than RD (98.01 ± 21.81 versus 48.58 ± 15.98 g, respectively; $P < 0.001$). Overall, macronutrient consumption during RD comprised 59.9% carbohydrates, 31% fat, and 12.4% protein and 32.97%, 44.58%, and 18.79% on NRD, respectively. The levels of intake of vitamins D and E and minerals (calcium, magnesium, and potassium) were below the recommended DRI during both RD and NRD [21,22]. Intake of iron (RD: 165.43 ± 60.20 and NRD: 135.47 ± 46.99% Dietary recommended intake (DRI), $P = 0.101$] and vitamin C (RD: 199.79 ± 156.66% and NRD: 173.41± 157.77% DRI, $P = 0.605$) was adequate, despite the restriction of meat products during fasting periods. Of major interest, vitamin D intake was very low during both RD and NRD (11.97 ± 21.78 versus 60.36 ± 77.38% Dietary recommended intake (DRI), respectively; $P = 0.001$).

Group 2: Athonian Monks

Table 3 presents macro- and micronutrient intake on RD and NRD for AM. We found that daily energy intake was low on NRD and even lower on RD (1571.55 ± 81.07 versus 1362.42 ± 84.52 kcal, respectively; $P < 0.001$). Fat intake was lower during NRD than RD (21.47 ± 1.96 versus 30.07 ± 0.17 g, respectively; $P < 0.001$). Total fat intake (%TEI) was low during both RD and NRD (19.93 ± 1.09% versus 12.28 ± 0.63%, respectively; $P < 0.001$). Protein intake was higher on RD than NRD both in absolute terms (89.24 ± 1.38 versus 72.35 ± 1.32 g, respectively; $P < 0.001$) and as a %TEI (26.28 ± 1.19% versus 18.47 ± 0.56%, respectively; $P < 0.001$). Overall, macronutrient consumption during RD comprised 46.64% carbohydrates, 19.93% fat, and 26.28% protein and 74.95%, 12.28%, and 18.47%, on NRD, respectively.

Table 2
Dietary and nutrient intakes on RD and NRD in the general population fasters group

Intake	RD	NRD	Test statistics
Energy (kcal)	1575.5 ± 285.96	2137.8 ± 470.84	$t(23) = -6.657$, $d = -1.473$, $r = 0.491$, $P < 0.001$
Carbohydrates (g)	235.20 ± 71.49	176.94 ± 51.19	$t(23) = 3.339$, $d = 0.688$, $r = 0.047$, $P = 0.003$
%TEI	59.9 ± 14.4	32.97 ± 6.24	$Z = -4.229$, $P < 0.001$
Fat (g)	54.94 ± 26.92	104.59 ± 31.22	$t(23) = -5.985$, $d = -1.19$, $r = 0.028$, $P < 0.001$
%TEI	31.0 ± 13.71	44.58 ± 9.23	$Z = -3.029$, $P = 0.002$
Protein (g)	48.58 ± 15.98	98.01 ± 21.81	$t(23) = -10.008$, $d = -2.04$, $r = 0.209$, $P < 0.001$
%TEI	12.4 ± 3.84	18.79 ± 4.63	$Z = -4.143$, $P < 0.001$
Saturated fat (g)	10.36 ± 8.13	34.97 ± 14.70	$t(23) = -7.650$, $d = -1.628$, $r = 0.142$, $P < 0.001$
Cholesterol (mg)	64.04 ± 145.90	372.21 ± 175.25	$t(23) = -6.497$, $d = -1.331$, $r = -0.039$, $P < 0.001$
Fiber (g)	38.74 ± 16.49	19.84 ± 10.87	$t(23) = 4.554$, $d = 0.946$, $r = -0.066$, $P < 0.001$
Ca (mg)	484.69 ± 263.02	887.61 ± 411.14	$t(23) = -3.667$, $d = -0.76$, $r = -0.238$, $P = 0.002$
%DRI	48.47 ± 26.31	86.02 ± 41.30	$Z = -3.072$, $P = 0.002$
Fe (mg)	16.54 ± 6.02	13.45 ± 4.68	$t(23) = 1.822$, $d = 0.368$, $r = -0.193$, $P = 0.079$
%DRI	165.43 ± 60.20	135.47 ± 46.99	$Z = -1.642$, $P = 0.101$
Mg (mg)	283.63 ± 130.77	240.90 ± 98.08	$t(23) = 1.367$, $d = 0.283$, $r = 0.127$, $P = 0.208$
%DRI	67.53 ± 31.14	58.02 ± 22.97	$Z = -1.095$, $P = 0.274$
Na (mg)	1767.56 ± 1007.20	3224.33 ± 1184.78	$t(23) = -4.113$, $d = -1.074$, $r = 0.234$, $P = 0.001$
%DRI	73.65 ± 41.97	130.90 ± 51.88	$Z = -3.102$, $P = 0.002$
K (mg)	2575.82 ± 1065.56	2790.70 ± 982.00	$t(23) = -0.841$, $d = -0.169$, $r = 0.231$, $P = 0.438$
%DRI	68.59 ± 28.41	74.85 ± 25.77	$Z = -0.639$, $P = 0.523$
Vit A (mcg)	732.90 ± 817.94	1209.66 ± 1245.59	$t(23) = -1.564$, $d = -2.435$, $r = 0.982$, $P = 0.162$
%DRI	73.29 ± 81.80	121.81 ± 124.57	$Z = -2.007$, $P = 0.045$
Vit B_{12} (mcg)	1.06 ± 1.63	5.61 ± 4.95	$t(23) = -5.165$, $d = -0.982$, $r = 0.008$, $P < 0.001$
%DRI	44.36 ± 67.75	227.92 ± 211.26	$Z = -3.848$, $P < 0.001$
Vit B_2 (mcg)	1.10 ± 0.38	1.75 ± 0.43	$t(23) = -5.176$, $d = -1.420$, $r = 0.361$, $P < 0.001$
%DRI	84.23 ± 29.01	132.92 ± 34.93	$Z = -3.650$, $P < 0.001$
Vit C (mcg)	119.88 ± 94.00	103.93 ± 94.74	$t(23) = 0.763$, $d = 0.112$, $r = 0.046$, $P = 0.523$
%DRI	199.79 ± 156.66	173.41 ± 157.77	$Z = -0.517$, $P = 0.605$
Vit D (mcg)	0.60 ± 1.09	3.14 ± 3.82	$t(23) = -3.057$, $d = -1.213$, $r = 0.636$, $P = 0.006$
%DRI	11.97 ± 21.78	60.36 ± 77.38	$Z = -3.255$, $P = 0.001$
Vit E (mcg)	8.31 ± 4.45	9.16 ± 4.25	$t(23) = -0.680$, $d = -0.606$, $r = 0.948$, $P = 0.551$
%DRI	83.10 ± 44.56	92.09 ± 42.03	$Z = -0.821$, $P = 0.412$

Ca, calcium; Fe, iron, K, potassium; Mg, magnesium; Na, sodium; NRD, nonrestrictive day; RD, restrictive day; %DRI, percentage of the dietary reference intake; %TEI, percentage of the daily total energy intake

Table 3
Dietary and nutrient intakes on RD and NRD for Athonian monks

Intake	RD	NRD	Test statistics
Energy (kcal)	1362.42 ± 84.52	1571.55 ± 81.07	$t(69) = -24.146$, $d = -2.890$, $r = 0.618$, $P < 0.001$
Carbohydrates (g)	159.6 ± 21.82	294.35 ± 23.40	$t(69) = -54.777$, $d = -6.565$, $r = 0.588$, $P < 0.001$
%TEI	46.64 ± 3.41	74.95 ± 2.43	$Z = -7.300$, $P < 0.001$
Fat (g)	30.07 ± 0.17	21.47 ± 1.96	$t(69) = 37.412$, $d = 7.66$, $r = 0.396$, $P < 0.001$
%TEI	19.93 ± 1.09	12.28 ± 0.63	$Z = -7.300$, $P < 0.001$
Protein (g)	89.24 ± 1.38	72.35 ± 1.32	$t(69) = 119.795$, $d = 14.315$, $r = 0.618$, $P < 0.001$
%TEI	26.28 ± 1.19	18.47 ± 0.56	$Z = -7.300$, $P < 0.001$
Saturated fat (g)*,†	12.75 ± 0.00	16.40 ± 0.00	–
Cholesterol (mg)*,†	181.00 ± 0.00	178.00 ± 0.00	–
Fiber (g)	23.42 ± 0.93	36.22 ± 0.89	$t(69) = -449.592$, $d = -60.530$, $r = 0.973$, $P < 0.001$
Ca (mg)	579.51 ± 2.29	665.69 ± 2.27	$t(69) = -2260.844$, $d = -267.274$, $r = 0.990$, $P < 0.001$
%DRI	57.94 ± 0.23	66.56 ± 0.22	$Z = -7.649$, $P < 0.001$
Fe (mg)	13.70 ± 0.00	18.13 ± 0.06	$t(69) = -619.482$, $P < 0.001$
%DRI	137.00 ± 0.00	181.30 ± 0.60	$Z = -7.722$, $P < 0.001$
Mg (mg)	167.43 ± 3.29	152.29 ± 3.14	$t(69) = 621.927$, $d = 105.300$, $r = 0.999$, $P < 0.001$
%DRI	39.84 ± 0.77	36.23 ± 0.74	$Z = -7.451$, $P < 0.001$
Na (mg)*,†	1733.00 ± 0.00	1549.00 ± 0.00	–
%DRI*,†	72.21 ± 0.00	64.54 ± 0.00	–
K (mg)	2539.00 ± 88.56	3755.59 ± 88.67	$t(69) = -20515.135$, $d = 0.00$, $r = 1.00$, $P < 0.001$
%DRI	67.63 ± 2.34	100.07 ± 2.34	$Z = -7.526$, $P < 0.001$
Vit A (mcg)	805.64 ± 24.26	708.26 ± 24.46	$t(69) = 1936.152$, $r = 1.00$, $P < 0.001$
%DRI	80.48 ± 2.40	70.74 ± 2.42	$Z = -7.414$, $P < 0.001$
Vit B_{12} (mcg)*,†	5.50 ± 0.00	5.60 ± 0.00	–
%DRI*,†	229.17 ± 0.00	233.33 ± 0.00	–
Vit B_2 (mcg)	1.01 ± 0.02	1.11 ± 0.02	$t(69) = -99.901$, $d = -20.412$, $r = 0.970$, $P < 0.001$
%DRI	77.44 ± 1.76	85.41 ± 1.26	$Z = -7.475$, $P < 0.001$
Vit C (mcg)	257.54 ± 2.99	373.78 ± 2.91	$t(69) = -3868.426$, $d = -508.696$, $r = 0.997$, $P < 0.001$
%DRI	429.04 ± 622.79	622.79 ± 4.79	$Z = -7.507$, $P < 0.001$
Vit D (mcg)*,†	1.00 ± 0.00	0.98 ± 0.00	–
%DRI*,†	20.00 ± 0.00	19.60 ± 0.00	–
Vit E (mcg)*,†	5.70 ± 0.00	13.80 ± 0.00	–
% DRI*,†	57.00 ± 0.00	138.00 ± 0.00	–

Ca, calcium; Fe, iron, K, potassium; Mg, magnesium; Na, sodium; NRD, nonrestrictive day; RD, restrictive day; %DRI, percentage of the dietary reference intake; %TEI, percentage of the daily total energy intake
*The correlation coefficient (r) and t test statistics (t) cannot be computed because the standard error of the difference is 0. Z denotes Wilcoxon-signed rank test statistics with P-value for exact significance (two-tailed).
†Effect size cannot be calculated because of the unifrom standard deviation (uniforms.d). or perfect correlation.

The levels of intake of vitamins A, B_2, D and minerals (calcium, magnesium, and sodium) were also below the recommended percent of DRI during both RD and NRD [21,22]. Remarkably, vitamin D intake was very low during both RD and NRD (20.00 ± 0 versus 19.60 ± 0 %DRI, respectively). In contrast, although meat consumption is totally restricted in Athonian COF, intake of vitamin B_{12} was adequate during both RD and NRD (229.17 ± 0 versus 233.33 ± 0 %DRI respectively), as was the intake of vitamin C (429.04 ± 622.79 versus 622.79 ± 4.79 %DRI, respectively; $P < 0.001$) and iron (137.00 ± 0 versus 181.30 ± 0.60 %DRI, respectively; $P < 0.001$).

Comparison of dietary and nutrient intake in fasting and nonfasting days between groups

Restrictive day

Table 4 presents macro- and micronutrient intake on RD in the two groups. A notable finding was that daily energy intake was considerably lower on RD in group 2 than for group 1 (1362.42 ± 84.52 versus 1575.47 ± 285.96 kcal, respectively; $P < 0.001$).

Carbohydrate and fat intake were higher in group 1 than in group 2 (235.20 ± 71.49 versus 159.60 ± 21.82 g, respectively; $P < 0.001$ and 54.94 ± 26.92 versus 30.07 ± 0.18 g, respectively; $P < 0.001$), whereas protein intake was higher on RD in group 2 than for group 1 (89.24 ± 1.38 versus 48.58 ± 15.99 g, respectively; $P < 0.001$). Total fat intake (%TEI) was significantly higher in group 1 than in group 2 (30.5 ± 15% versus 19.93 ± 1.09%, respectively; $P < 0.001$). Overall, macronutrient consumption during RD for groups 1 and 2 included 60.3% carbohydrates, 30.5% fat, and 12.5% protein and 46.64%, 19.93%, and 26.28%, respectively.

Saturated fat intake was low in both groups 1 and 2 (10.36 ± 8.13 versus 12.75 ± 0.00 g, respectively; $P = 0.015$),whereas cholesterol intake was higher in group 2 than in group 1 (181.00 ± 0.00 versus 64.04 ± 145.90 mg, respectively; $P < 0.001$).

The levels of intake of many vitamins (C, D, and E) and minerals (calcium, iron, and magnesium) significantly differed between the two groups. In Specifically, intake of vitamins C and B_{12} was two- to threefold higher in group 2 than in group 1 (257.54 ± 2.99 versus 119.88 ± 94.00 mcg, respectively; $P < 0.001$ and 5.50 ± 0.00 versus 1.06 ± 1.63 mcg, respectively; $P < 0.001$). On the other hand, in both groups mineral intake (calcium, magnesium, sodium, and postassium) were below the recommended percent of DRI [21,22].

Nonrestrictive day

Table 5 presents macro-t and micronutrient intake on NRD for both groups. Daily energy intake was considerably lower in group 2 than in group 1 (1571.55 ± 81.07 versus 2137.80 ± 470.84 kcal, respectively; $P < 0.001$). Carbohydrate intake was notably higher in group 2 than in group 1 both in terms of absolute intake (294.35 ± 23.40 versus 176.63 ± 51.19 g, respectively; $P < .001$) and as a %TEI (74.95 ± 2.43 versus 33.39 ± 6.03, respectively; $P < 0.001$). Fat and protein intakes were higher in group 1 than in group 2 (104.59 ± 31.22 versus 21.47 ± 1.96 g, respectively; $P < 0.001$ and 98.01 ± 21.81 versus 72.35 ± 1.32 g, respectively; $P < 0.001$).

Table 4
Dietary and nutrient intakes of general population fasters and Athonian monks on restrictive day

Intake	Group 1: General population fasters	Group 2: Athonian monks	Test statistics
Energy (kcal)	1575.47 ± 285.96	1362.42 ± 84.52	$t(92) = 5.607$, $d = 1.150$, $P < 0.001$
Carbohydrates (g)	235.20 ± 71.49	159.60 ± 21.82	$t(92) = 7.905$, $d = 1.620$, $P < 0.001$
%TEI	60.3 ± 18.5	46.64 ± 3.41	$Z = -4.792$, $P < 0.001$
Fat (g)	54.94 ± 26.92	30.07 ± 0.18	$t(92) = 7.809$, $d = 1.835$, $P < 0.001$
%TEI	30.5 ± 15	19.93 ± 1.09	$Z = -3.634$, $P < 0.001$
Protein (g)	48.58 ± 15.99	89.24 ± 1.38	$t(92) = -21.268$, $d = -4.682$, $P < 0.001$
%TEI	12.5 ± 4.1	26.28 ± 1.19	$Z = -7.224$, $P < 0.001$
Saturated fat (g)	10.36 ± 8.13	12.75 ± 0.00	$t(92) = -2.484$, $d = -0.294$, $P = 0.015$
Cholesterol (mg)	64.04 ± 145.90	181.00 ± 0.00	$t(92) = -6.778$, $d = -0.802$, $P < 0.001$
Fiber (g)	38.74 ± 16.49	23.42 ± 0.93	$t(92) = 7.818$, $d = 1.759$, $P < 0.001$
Ca (mg)	484.69 ± 263.02	579.51 ± 2.29	$t(92) = -3.048$, $d = -0.715$, $P = 0.003$
%DRI	48.60 ± 26.88	57.94 ± 0.23	$Z = -4.088$, $P < 0.001$
Fe (mg)	16.53 ± 6.02	13.7 ± 0.00	$t(92) = 3.993$, $d = 0.470$, $P < 0.001$
%DRI	167.30 ± 60.84	137.00 ± 0.00	$Z = -4.527$, $P < 0.001$
Mg (mg)	283.63 ± 130.77	167.43 ± 3.29	$t(92) = 7.506$, $d = 1.734$, $P < 0.001$
%DRI	67.34 ± 31.82	39.84 ± 0.77	$Z = -4.303$, $P < 0.001$
Na (mg)	1767.56 ± 1007.20	1733.00 ± 0.00	$t(92) = 0.290$, $d = 0.034$, $P = 0.772$
%DRI	74.91 ± 42.78	72.21 ± 0.00	$Z = -0.412$, $P = 0.524$
K (mg)	2575.82 ± 1065.56	2539.00 ± 88.56	$t(92) = 0.289$, $d = 0.064$, $P = 0.773$
%DRI	69.08 ± 28.99	67.63 ± 2.34	$Z = -0.638$, $P = .524$
Vit A (mcg)	732.90 ± 817.94	805.64 ± 24.26	$t(92) = -0.751$, $d = -0.173$, $P = 0.455$
%DRI	75.13 ± 83.12	80.48 ± 2.40	$Z = -0.702$, $P = 0.004$
Vit B_{12} (mcg)	1.06 ± 1.63	5.50 ± 0.00	$t(92) = -23.064$, $d = -2.724$, $P < 0.001$
%DRI	45.33 ± 69.10	229.17 ± 0.00	$Z = -8.642$, $P < 0.001$
Vit B_2 (mcg)	1.10 ± 0.38	1.01 ± 0.02	$t(92) = 1.949$, $d = 0.450$, $P = 0.054$
%DRI	85.25 ± 29.22	77.44 ± 1.76	$Z = -0.709$, $P = 0.478$
Vit C (mcg)	119.88 ± 94.00	257.54 ± 2.99	$t(92) = -12.364$, $d = -2.839$, $P < 0.001$
%DRI	200.33 ± 160.16	429.04 ± 4.95	$Z = -6.010$, $P < 0.001$
Vit D (mcg)	0.60 ± 1.09	1.00 ± 0.00	$t(92) = -3.119$, $d = -0.367$, $P = 0.002$
%DRI	12.41 ± 22.16	20.00 ± 0.00	$Z = -8.642$, $P < 0.001$
Vit E (mcg)	8.31 ± 4.45	5.71 ± 0.30	$t(92) = 4.914$, $d = 1.095$, $P < 0.001$
%DRI	80.77 ± 43.93	57.00 ± 3.00	$Z = -3.135$, $P = 0.002$

Ca, calcium; Fe, iron, K, potassium; Mg, magnesium; Na, sodium; %DRI, percentage of the dietary reference intake; %TEI, percentage of the daily total energy intake

Table 5
Dietary and nutrient intakes of general population fasters and Athonian monks on nonrestrictive day

Intake	Group 1: General population fasters	Group 2: Athonian monks	Test statistics
Energy (kcal)	2137.80 ± 470.84	1571.55 ± 81.07	$t(92) = 9.744$, $d = 2.052$, $P < 0.001$
Carbohydrates (g)	176.63 ± 51.19	294.35 ± 23.40	$t(92) = -15.243$, $d = -3.156$, $P < 0.001$
%TEI	33.39 ± 6.03	74.95 ± 2.43	$Z = -7.236$, $P < 0.001$
Fat (g)	104.59 ± 31.22	21.47 ± 1.96	$t(92) = 22.378$, $d = 5.010$, $P < 0.001$
%TEI	43.95 ± 9.27	12.28 ± 0.63	$Z = -7.236$, $P < 0.001$
Protein (g)	98.01 ± 21.81	72.35 ± 1.32	$t(92) = 9.894$, $d = 2.219$, $P < 0.001$
%TEI	18.84 ± 4.73	18.47 ± 0.56	$Z = -0.989$, $P = .323$
Saturated fat (g)	34.97 ± 14.70	16.40 ± 0.00	$t(92) = 10.678$, $d = 1.263$, $P < 0.001$
Cholesterol (mg)	372.21 ± 175.25	178.00 ± 0.00	$t(92) = 9.370$, $d = 1.108$, $P < 0.001$
Fiber (g)	19.84 ± 10.87	36.22 ± 0.89	$t(92) = -12.617$, $d = -2.786$, $P < 0.001$
Ca (mg)	887.61 ± 411.14	665.69 ± 2.27	$t(92) = 4.564$, $d = 1.074$, $P < 0.001$
%DRI	85.82 ± 42.22	66.56 ± 0.22	$Z = -3.045$, $P = 0.002$
Fe (mg)	13.45 ± 4.68	18.13 ± 0.06	$t(92) = -8.442$, $d = $ v1.975, $P < 0.001$
%DRI	135.83 ± 48.02	181.30 ± 0.60	$Z = -5.914$, $P < 0.001$
Mg (mg)	240.92 ± 98.08	152.29 ± 3.14	$t(92) = 7.627$, $d = 1.751$, $P < 0.001$
%DRI	57.94 ± 23.48	36.23 ± 0.74	$Z = 5.345$, $P < 0.001$
Na (mg)	3224.33 ± 1184.78	1549.00 ± 0.00	$t(92) = 11.956$, $d = 1.414$, $P < 0.001$
%DRI	131.04 ± 53.04	64.54 ± 0.00	$Z = -6.996$, $P < 0.001$
K (mg)	2790.70 ± 982.00	3755.59 ± 88.87	$t(92) = -8.208$, $d = -1.802$, $P < 0.001$
%DRI	75.16 ± 26.30	100.07 ± 2.34	$Z = $ v5.435, $P < 0.001$
Vit A (mcg)	1209.66 ± 1245.59	708.26 ± 24.46	$t(92) = 3.402$, $d = 0.790$, $P = 0.001$
%DRI	122.04 ± 127.47	70.74 ± 2.42	$Z = -2.134$, $P = 0.033$
Vit B12 (mcg)	5.62 ± 4.95	5.60 ± 0.00	$t(92) = 0.029$, $d = 0.004$, $P = 0.977$
%DRI	231.18 ± 215.18	233.33 ± 0.00	$Z = -2.058$, $P = 0.040$
Vit B2 (mcg)	1.75 ± 0.43	1.11 ± 0.02	$t(92) = 12.656$, $d = 2.844$, $P < 0.001$
%DRI	133.11 ± 35.71	85.41 ± 1.26	$Z = -6.052$, $P < 0.001$
Vit C (mcg)	103.93 ± 94.74	373.78 ± 2.91	$t(92) = -24.048$, $d = $ -5.527, $P < 0.001$
%DRI	176.98 ± 160.32	622.78 ± 4.79	$Z = -7.232$, $P < 0.001$
Vit D (mcg)	3.14 ± 3.82	0.98 ± 0.00	$t(92) = 4.787$, $d = 0.565$, $P < 0.001$
%DRI	62.33 ± 78.50	19.60 ± 0.00	$Z = $ v3.704, $P < 0.001$
Vit E (mcg)	9.16 ± 4.25	13.81 ± 0.30	$t(92) = $ v9.191, $d = -2.044$, $P < 0.001$
%DRI	89.18 ± 40.43	138.00 ± 3.00	$Z = -4.707$, $P < 0.001$

Ca, calcium; Fe, iron, K, potassium; Mg, magnesium; Na, sodium; %DRI, percentage of the dietary reference intake; %TEI, percentage of the daily total energy intake

Table 6
Cardiometabolic markers in general population fasters and Athonian monks

Biochemical Marker	Group 1: General population fasters	Group 2: Athonian monks	Test statistics
CRP (mg/dL)	0.37 ± 0.61	–	–
CHOL (mg/dL)	189.1 ± 45.08	183.00 ± 40.87	$t(99.758) = 0.725$, $d = 0.142$, $P = 0.470$
TRIG (mg/dL)	113.22 ± 79.09	73.82 ± 31.68	$t(105) = 3.460$, $d = 0.711$, $P = 0.001$
HDL-C (mg/dL)	43.20 ± 11.05	47.83 ± 14.11	$t(103.733) = -1.898$, $d = -0.368$, $P = 0.061$
LDL-C (mg/dL)	120.68 ± 45.92	119.97 ± 36.70	$t(93.582) = 0.088$, $d = 0.017$, $P = 0.930$
Calcium (mg/dL)	9.01 ± 1.27	9.06 ± 0.42	$t(112) = -0.270$, $d = -0.059$, $P = 0.788$
Phosphorus (mg/dL)	3.58 ± 0.86	–	–
Insulin (μg/mL)	11.64 ± 9.21	4.61 ± 3.16	$t(100) = 5.150$, $d = 1.137$, $P < 0.001$
PTH (pg/mL)	37.69 ± 16.36	116.09 ± 49.75	$t(110) = -11.283$, $d = -2.372$, $P < 0.001$
125(OH)2D:Calcitriol	27.93 ± 36.00	–	–
1α25(OH)D3:1α,calcifediol	5018.50 ± 2158.22	–	–
25(OH)D2	32.34 ± 39.51	–	–
25(OH)D (ng/mL)	28.26 ± 39.66	9.27 ± 5.81	$t(103) = 3.448$, $d = 0.839$, $P = 0.001$
Glucose (mmol/L)	5.12 ± 0.32	4.71 ± 0.60	$t(114) = 4.645$, $d = 0.891$, $P < 0.001$
Uric acid (mg/dL)	–	4.72 ± 0.90	–
AST UL	–	28.37 ± 13.64	–
ALT UL	–	26.04 ± 9.31	–
HOMA-IR (mmol/L)	2.67 ± 2.19	0.98 ± 0.72	$t(100) = 5.229$, $d = 1.162$, $P < 0.001$
Ferritin (ng/mL)	–	77.65 ± 37.92	–

CRP, C-reactive protein; ALT, aalanine transaminase; AST, aspartate transaminase; CHOL, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PTH, Pparathyroid hormone; TRIG, triacylglycerol; 25(OH)D, 25-hydroxyvitamin-D; HOMA-IR, homeostatic model assessment for insulin resistance

Overall, macronutrient consumption during NRD comprised 33.39% carbohydrates, 43.95% fat, and 18.84% protein for group 1 and 74.95%, 12.28%, and 18.47%, respectively, for group 2. Saturated fat and cholesterol intake was higher in group 1 than in group 2 (34.97 ± 14.70 versus 16.40 ± 0 g, respectively; $P < 0.001$ and 372.21 ± 175.25 versus 178.00 ± 0.00 mg, respectively; $P < 0.001$). Intake levels of magnesium and calcium were below the recommended percent of DRI [21,22] for both groups, whereas sodium intake was markedly lower for group 2 than for group 1 (1549.00 ± 0.00 versus 3224.33 ± 1184.78 mg, respectively; $P < 0.001$). Intake of vitamin B_{12} was adequate for both groups 1 and 2 (231.18 versus 233.3 %DRI, respectively; $P = 0.040$), as was the intake of vitamin C (176.98 versus 622.78 %DRI, respectively; $P < 0.001$) and iron (135.83 versus 181.3 %DRI, respectively; $P < 0.001$).

Cardiometabolic parameters

Table 6 shows the cardiometabolic markers of the two groups. In detail, groups 1 and 2 demonstrated a comparable profile for total cholesterol (TC; 189.1 ± 45.08 versus 183.00 ± 40.87 mg/dL, respectively; $P = 0.470$) and low-density lipoprotein cholesterol (LDL-C; 120.68 ± 45.92 versus 119.97 ± 36.70 mg/dL, respectively; $P = 0.930$), whereas high-density lipoprotein cholesterol (HDL-C) concentrations were in the low–normal range for both groups (43.20 ± 11.05 versus 47.83 ± 14.11 mg/dL, respectively; $P = 0.061$). Regarding glucose homeostasis, group 2 demonstrated a more favorable profile on fasting insulin concentrations and HOMA-IR values compared with group 1 (4.61 ± 3.16 versus 11.64 ± 9.21 μU/mL, respectively; $P < 0.001$ and 0.98 ± 0.72 versus 2.67 ± 2.19 mmol/L, respectively; $P < 0.001$).

Concerning calcium homeostasis, parathyroid hormone (PTH) was found to be significantly elevated in group 2 (116.09 ± 49.75 pg/mL), whereas serum calcium was within the normal range (9.06 ± 0.42 mg/dL). It is worth pointing out that all monks were vitamin D deficient with levels at 9.27 ± 5.81 ng/mL.

Discussion

To our knowledge, this is the first comparative report in the literature of dietary intake, anthropometric, and cardiometabolic markers in two distinct groups of Orthodox fasters—monks and general population. Significant differences in nutritional patterns between RD and NRD were evident between the two groups, in conjunction with a more favorable profile of anthropometric and glucose homeostasis in the AM group compared with the GF group, with the exception of profound hypovitaminosis D.

The daily relative energy intake (REI) is individualized and dependent on a variety of factors, such as age, sex, and physical activity. However, it could be estimated that the mean energy intakes of 1362.4 and 1567.6 kcal that monks consume during RD and NRD, respectively, correspond to ~46.5% and 53.5% of the daily REI for a moderately active male, 20 and 45 y of age, according to recommendations [22]. On the other hand, the mean energy intake for the GF group during RD and NRD account for ~53.5% and 72.3% of the REI, respectively.

Calorie restriction has been described as an important characteristic of COF [10,11]. According to the results of the present study, calorie intake was lower during RD than during NRD in both groups, whereas AM demonstrated significantly lower total calorie intake for both days. This phenomenon was probably the result of their strict adherence to the traditional Athonian dietary pattern, including only two main meals per day compared to the typical COF followed by the general Orthodox population. Dietary temperance is considered to be a primary element of the Athonian lifestyle and nutritional behavior [10,11].There is growing evidence connecting calorie restriction to significant health benefits through a variety of mechanisms, such as activation of cellular stress response elements, increased autophagy, adjustment of apoptosis, and changes in hormonal environment [33].

Notable nutrient intake differences were also evident among the study groups on both RD and NRD. The GF group demonstrated an increased intake of carbohydrates (60.3%) and fat (30.5%) during RD compared with the AM group (46.64% and 19.93%, respectively). A higher fat intake compared with AM was also evident during NRD (43.95 versus 12.28%, respectively). As previously demonstrated [11], Athonian fasting is characterized by a remarkable restraint of total fat intake compared with the traditional MD pattern, followed by the GF included in this analysis, which comprises 37% to 40% of TEI as fat, mostly from fish and plant sources [5–7,21,34].

Dietary protein and fat intake during COF in Athos is mainly from fish, olive oil, dairy products, and seeds, given that meat consumption is forbidden and legumes, fruits, beans, and nuts are the principal food alternatives [8,11]. This nutritional model has been

reported to provide an increased intake of monounsatured fatty acids (MUFAs) and ω-6 and ω-3 polyunsaturated fatty acids (PUFAs). It is now recognized that MUFAs found in extra virgin olive oil, used as the only source of dietary oil in Athos [10,11], and ω-3 PUFAs mainly obtained from fish, contribute to the beneficial effects of the MD, as previously reported in studies of Crete's population [5,12,13]. As previously described [35], there are important differences between the MD and the Western diet regarding the quantity and sources of MUFA and the quantity of ω-6 and ω-3 PUFAs. Results of the PREDIMED (Prevention with Mediterranean Diet) trial [36] demonstrated that a typical MD, although of relatively high-fat intake (35–40%) compared with the nutritional model suggested by the American Heart Association (AHA) guidelines [37] for preventing cardiovascular disease (CVD), was positively associated with primary CVD prevention. These observations raised concerns [38] about recommending a low-fat diet, which coupled with the widespread availability of zero- or low-fat foods, could actually favor higher consumption of refined starch- and sugar-rich foods, thus contributing to excessive energy intake. In support of this concern, there is some evidence that both MUFAs and PUFAs in the Mediterranean eating pattern tend to reduce LDL-C and total cholesterol (TC), while increasing HDL-C [11,39]. Moreover, with the exception of a threefold increase during NRD compared with RD in the general population, consumption of saturated fat was remarkably lower than in typical northern Europe and Western population eating patterns [35–37].

Lipid and glucose profiles were optimal for the majority of included participants and consistent with recommendations [37]. However, HDL-C concentrations were in the lower normal range, a finding previously described with consumption of low-calorie and vegetarian diets [40]. AM demonstrated a favorable glucose homeostasis profile compared with the GF group, despite the fact that they consume a remarkable amount of carbohydrates (74.95 %TEI) during NRD. In particular, markers for insulin resistance were significantly lower in monks than in the GF group, using HOMA-IR [24]. Although fasting glucose concentrations were significantly lower in monks than in GF (4.71 ± 0.60 versus 5.12 ± 0.32 mmol/L, respectively; $P < 0.001$), fasting insulin concentrations were almost threefold lower in monks (4.61 ± 3.16 versus 11.64 ± 9.21 μg/mL, respectively; $P < 0.001$). Fasting insulin levels have been shown to highly correlate with HOMA-IR measurements [41]. This lower insulin resistance in the monks is highly favorable because insulin resistance has been proposed as a central mediator of several noncommunicable diseases characterized by chronic inflammation [42–46]. The lower insulin resistance seen in the monks likely relates to their lower BMI, BF, and VF compared with the GF group (Table 1), combined with increased physical activity incorporated into their daily schedule. Visceral adiposity is associated with metabolic abnormalities including insulin resistance, abnormal blood lipids, and non-alcoholic fatty liver disease [44]. It is of interest that the periodic fasting of lay people did not appear to protect them from overweight or from relatively higher VF compared with monks (Table 1). Periodic fasting such as that proposed by popular diets (e.g., 5:2 diet) is advocated as an alternative to continuous energy restriction for weight management [47,48], with the potential to improve metabolic biomarkers [6,9,49]. However, the effect on clinical outcomes such as Alzheimer's disease, diabetes, CVD, or cancer is currently unclear [50].

The results of the present study also confirmed previous findings [10,11] regarding the existence of severe hypovitaminosis D between Orthodox monks. A potential explanation for the aforementioned observation is the fact that persons under religious order have to wear black cassocks during their outdoor activities; thus, this can have a negative effect on their vitamin D status. Comparable findings have been reported in other populations of the Mediterranean region, in whom cutaneous vitamin D production is affected by clothing preference [51,52].

The present study presented specific limitations. The number of included participants was relatively small; however, we consider that it was representative because the monk's community in Athos follows a common dietary and physical activity plan. The present analysis has not taken into account the seasonal changes in vitamin D concentrations, given that relative data from summer months is missing. Finally, this is a cross-sectional study, and thus we were unable to establish causal associations.

Conclusion

This study offers, for the first time, detailed appraisal of COF, as practiced in Mount Athos, in a comparative evaluation with the typical COF, as practiced by the general Orthodox population. Its results highlight the unique characteristics of Athonian fasting and its value as a health-promoting diet.

We consider that the positive effect of this nutritional model on human homeostasis is facilitated by a variety of valuable mechanisms, extended beyond the benefits of a typical vegetarian diet. These mechanisms mainly include calorie restriction combined with augmented intake of high nutritional quality, organic foods, mostly produced by the monks themselves within the community of Mount Athos and thus free of genetically modified ingredients. Future trials are necessary to investigate the role of COF as medical nutrition therapy for chronic metabolic diseases and the potential effects of limited intake of specific vitamins and minerals during fasting.

Acknowledgment

The authors acknowledge the "Holy Supervision Council" and the community of monks at Mount Athos for their participation.

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