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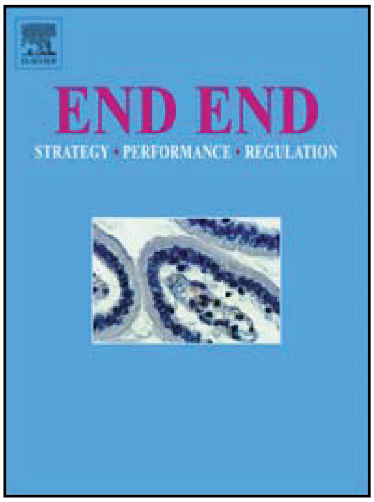

Christian Orthodox fasting in practice: a comparative evaluation between Greek Orthodox general population fasters and Athonian monks

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Highlights

- Orthodox fasting (OF) is a periodical vegetarian subset of the Mediterranean diet
- We evaluated OF effects in general population fasters (GF) and Athonian monks (AM)
- AM demonstrated lower BMI, Body Fat Mass and HOMA-IR values compared to GF
- The results highlight the unique characteristics of Athonian OF as a health-promoting diet
- Limitation of specific vitamins and minerals during OF warrants further investigation

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

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Short Title: Health benefits of Orthodox fasting in Athos monks and general population

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Author contributions

SNK conceptualised and designed the study. SNK collected all data. SNK, TK AP, DF, DS, HM and KK analysed and interpreted the dietary data, SNK, TK, HM, PZ and DPN interpreted biochemical results. MK conducted biochemical analysis of the samples. AP and DF performed the literature review and performed the statistical analysis. SNK drafted the first version of the manuscript. All authors have read and critically revised the manuscript and approved the final version.

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Research involving human participants and/or animals

This article does not contain any studies with animals performed by any of the authors.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent: Informed consent was obtained from all individual participants included in the study.

Abstract

Objective: 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 impact in general population fasters (GF) and Athonian monks (AM), separately. This is the first study to comparatively evaluate the characteristics and effects of this nutritional advocacy between the two populations.

Methods: 43 general population male fasters (aged 20-45 years) and 57 age-matched male monks following COF were included in the study. Dietary intake data were collected in both groups during a restrictive (RD) and a non-restrictive (NRD) day. Nutritional, cardiometabolic and anthropometric parameters were compared between the two cohorts.

Results: AM compared to GF, presented lower daily total caloric intake for both RD(1362.42±84.52 vs 1575.47±285.96 kcal, p<.001) and NRD (1571.55±81.07 vs2137.80±470.84kcal, p<.001).They also demonstrated lower Body Mass Index (23.77±3.91 vs 28.92±4.50 kg/m^2, p<.001), Body Fat mass (14.57±8.98 vs 24.61±11.18 kg, p=.001) and Homeostatic Model Assessment for Insulin Resistance values(0.98±0.72 vs 2.67±2.19 mmol/l, p<.001),compared to 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 impact of limitation of specific vitamins and minerals during fasting warrants further investigation.

Key words: Christian Orthodox fasting; Mediterranean diet; Nutrient intake; Cardiometabolic markers; Calcium homeostasis; Lipids

Introduction

Previous research [1-4], has indicated the Mediterranean diet (MD) as 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 behaviour 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 population for prolonged periods (from 120 to 180 days) annually [8].COF has been suggested to share the beneficial effects of the typical MD by promoting specific cardio-protective mechanisms, including reduced intake of dietary cholesterol, 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 caloric intake is evident during COF periods, accentuating COF as a unique component of both caloric and dietary restriction regimen, among the other well-investigated religious 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 theMD. 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 centre of Eastern Orthodox monasticism [11]. A total population of approximately 1800 male monks is residing in twenty different monasteries, following a strict dietary and physical activity daily plan, incorporated 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 non-fasting 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, practicing fasting rituals from early adulthood as periodical fasters, with a discourse on: i) the similarities and differences in practicing COF between the two cohorts and ii) 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 a total of 43 Christian orthodox male adults (Group 1), aged 20-45 years, residing in the region of Chalkidiki, Northern Greece and an age-matched cohort of57Orthodox male Athonian monks (AM), from the monasterial community of Mount Athos (Group 2).Individuals with at least 6 months of adherence to COF were included in the study. Subjects with chronic diseases, receiving medication and/or vitamin or mineral supplements were excluded. Inclusion and exclusion criteria for the recruitment of participants in the present study have been previously described in detail [11].

Study design

Dietary analysis

Dietary intakes were analysed during two days of COF: a day during a weekend of Nativity Fast, where fish, olive oil, cereals, legumes, nuts, vegetables, fruits and alcohol are allowed, defined as 'non-restrictive day' (NRD), and a weekday during Great Lent, where olive oil and fish are additionally excluded from the regular nutritional plan, named as 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 dietician. The accuracy of estimation of portion sizes was based on standardized photo albums [17-19]. The protocol followed for the dietary analysis has been 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 9kcals/gram respectively for carbohydrates, protein and fat [23].

Anthropometric measurements and biochemical analysis

Anthropometric measurements and biochemical analyses were performed in both groups using standardised procedures. Exact methods, reference ranges, equipment used and other details have been 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, USA Onrion IIc); 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 metres squared (kg/m^2) [24]. Body Fat (BF) mass and percentage, Visceral Fat (VF), Muscle Mass (MM), Fat-free Mass (FFM) and Total Body Water (TBW) were measured using bioelectrical impedance analysis (BIA) (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) X FPG (mmol/L)/22.5].

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 months prior to study initiation (Constitutive Chart of Mount Athos –Greek Constitution 1975/86 art. 105 & 1-5).

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 vs. 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 the ease of interpretation and facilitating meta-analysis in the future, group statistics are reported as means and standard deviation, even when nonparametric statistics were used to test for statistical significance between the two groups. Following the recommended reporting guidelines for medical and behavioural research [27], means and standard deviations 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 $p < .05$ (non-directional) for all statistical tests. Data analyses were performed using SPSS v25. 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 Group 1 (GF) adhered to COF periodical patterns from early adulthood (mean duration: 19.2±4.5 years).The monks group adhered to religious fasting continually, since the beginning of their monastic life (mean duration: 13.27±8.9 years).Median BMI and %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 vs 28.92±4.50, p<.001), BF mass (14.57±8.98 vs 24.61±11.18 kg, p=.001), Waist Circumference values (83.26±4.23 vs 94.32±3.32 cm, p<.001),and VF mass (7.08±4.50 vs 13.49±5.87 kg,p<.001) compared to Group 1.

Comparison of dietary and nutrient intake in fasting- and non-fasting days

Group 1 (General population fasters)

Table 2 presents macronutrient and micronutrient intake on RD and NRD for Group 1. A key finding was that daily energy intake was considerably lower on RD compared to NRD (1575.5±285.96vs2137.8±470.84kcal respectively; p<.001). Fat intake was lower during RD compared with NRD (54.94±26.92 vs104.59±31.22 g respectively; p<.001). Total fat intake [% total energy intake (TEI)] differed significantly between RD and NRD (31.0±13.71 vs44.58±9.23% respectively; p=.002).Protein intake was higher on NRD, compared to RD (98.01±21.81vs48.58±15.98 g respectively; p<.001). Overall, macronutrient consumption during RD comprised of 59.9% carbohydrates, 31% fat and 12.4% protein and 32.97%, 44.58%and18.79% on NRD, respectively. The levels of intake of vitamins D and E and minerals (Ca, Mg, and K) were below the recommended DRI, during both RD and NRD [21,22]. Intake of Fe [165.43±60.20 (RD) and 135.47±46.99 (NRD) % DRI, p=.101] and vitamin C [199.79±156.66 (RD) and 173.41±157.77 (NRD) % DRI, p=.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±21.78vs60.36±77.38% DRI respectively; p=.001).

Group 2 (Athonian Monks)

Table 3 presents macronutrient 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±81.07vs1362.42±84.52kcal respectively; p<.001). Fat intake was lower during NRD compared to RD (21.47±1.96 vs30.07±0.17g respectively; p<.001). Total fat intake (% TEI) was low during both RD and NRD (19.93±1.09 vs12.28±0.63% respectively; p<.001). Protein intake was higher on RD, compared to NRD both in absolute terms (89.24±1.38vs72.35±1.32g respectively; p<.001) and as a % of TEI (26.28±1.19 vs 18.47±0.56% respectively; p<.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.

The levels of intake of vitamins A, B_2, D and minerals (Ca, Mg, Na) were also below the recommended % of DRI during both RD and NRD [21,22].Remarkably, vitamin D intake was very low during both RD and NRD (20.00±0.0 vs 19.60±0.0 % 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±0.0 vs 233.33±0.0 % DRI respectively),as was the intake of vitamin C (429.04±622.79 vs622.79±4.79 % DRI respectively; p<.001) and Fe (137.00±0.0 vs181.30±0.60 % DRI respectively; p<.001).

Comparison of dietary and nutrient intake in fasting- and non-fasting days between groups

Restrictive day

Table 4 presents macronutrient 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 compared to Group 1(1362.42±84.52 vs1575.47±285.96kcal respectively; p<.001). Carbohydrate and fat intake were higher in Group 1 (GF) compared to Group 2 (AM) (235.20±71.49 vs159.60±21.82 g respectively; p<.001 and 54.94±26.92 vs30.07±0.18 g respectively; p<.001),whereas protein intake was higher on RD in Group 2 compared to Group 1 (89.24±1.38 vs48.58±15.99 g respectively; p<.001).Total fat intake (%TEI) was significantly higher in Group 1 than in Group 2 (30.5±15.0 vs19.93±1.09% respectively; p<.001).Overall, macronutrient consumption during RD for Group 1 and 2included 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±8.13vs 12.75±0.00 g respectively; p=.015),whereas cholesterol intake was higher in Group 2 compared to Group 1(181.00±0.00 vs64.04±145.90 mg respectively; p<.001).

The levels of intake of many vitamins (C,D and E) and minerals (Ca, Fe, Mg) significantly differed between the two groups. In specific, vitamin C and B_{12} intake was 2 to 3–fold higher in Group 2 compared to Group 1 (257.54±2.99 vs119.88±94.00mcg respectively; p<.001and 5.50±0.00 vs 1.06±1.63 mcg, respectively; p<.001).On the other hand, in both groups mineral intake (Ca, Mg, Na,K) were below the recommended % of DRI [21,22].

Non-restrictive day

Table 5 presents macronutrient and micronutrient intake on NRD for both groups. Daily energy intake was considerably lower in Group 2 compared to Group 1(1571.55±81.07 vs2137.80±470.84kcal respectively; p<.001). Carbohydrate intake was notably higher in Group 2 than in Group 1both in terms of absolute intake (294.35±23.40 vs176.63±51.19 g respectively; p<.001),and as a % TEI (74.95±2.43 vs 33.39±6.03 respectively; p<.001). Fat and protein intakes were higher in Group 1 compared to Group 2 (104.59±31.22 vs21.47±1.96 g respectively; p<.001and 98.01±21.81 vs72.35±1.32 g respectively; p<.001).

Overall, macronutrient consumption during NRD comprised of 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±14.70vs16.40±0.0 g respectively; p<.001and 372.21±175.25vs178.00±0.00 mg respectively; p<.001).The levels of intake of Mg and Ca, were below the recommended % of DRI [21,22] for both groups, whereas Na intake was markedly lower for Group 2 compared to Group 1 (1549.00±0.00 vs 3224.33±1184.78 mg respectively; p<.001).Intake of vitamin B_{12} was adequate for both Groups 1 and 2(231.18 vs 233.3 % DRI respectively; p=.040), as was the intake of vitamin C (176.98 vs 622.78% DRI respectively; p<.001) and Fe (135.83 vs 181.3 % DRI, respectively; p<.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±45.08vs 183.00±40.87 mg/dl respectively; p=.470) and Low-Density Lipoprotein (LDL-C)(120.68±45.92vs119.97±36.70mg/dl respectively; p=.930), while High-Density Lipoprotein (HDL-C) concentrations were in the low–normal range for both (43.20±11.05vs 47.83±14.11 mg/dl respectively; p=.061).Regarding glucose homeostasis, Group 2 demonstrated a more favourable profile on fasting insulin concentrations and Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) values, compared to general population (4.61±3.16vs11.64±9.21 μU/ml respectively; p<.001 and 0.98±0.72 vs2.67±2.19 mmol/l respectively; p<.001).

Concerning calcium homeostasis, Parathyroid Hormone (PTH) was found to be significantly elevated in the monks group (116.09±49.75pg/ml), while 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 [25(OH) D levels 9.27±5.81ng/ml].

Discussion

This study 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 favourable profile of anthropometric and glucose homeostasis in the AM group compared to the general population, with the exception of profound hypovitaminosis D.

The daily, Recommended Energy Intake (REI) is individualized and dependent on a variety of factors, such as age, sex and physical activity, among others. However, it could be estimated that the mean energy intakes of 1362.4and 1567.6 kcal that monks consume during a RD and NRD respectively, correspond to approximately46.5% and 53.5% of the daily, REI for a moderately active male, aged between 20 and 45 years, according to recommendations [22]. On the other hand, general fasters' mean energy intakes during a RD and NRD account for about 53.5% and 72.3% of the REI, respectively.

Caloric restriction has been described as an important characteristic of COF [10, 11].According to the results of the present study,caloric intake was lower during RD compared to NRD in both groups, whereas AM demonstrated significantly lower total caloric intake for both days. This phenomenon was probably the result of their strict adherence to the traditional Athonian dietary pattern, including only two main mealsdaily, compared to the typical COF followed by the general Orthodox population. Dietary temperance is considered to be a primaryelement of the Athonian lifestyle and nutritional behavior [10,11].There is growing evidence connecting caloric 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 study groups on both RD and NRD. General population demonstrated an increased intake of carbohydrates(60.3%) and fat (30.5%) during RD compared to AM (46.64% and 19.93%, respectively).A higher fat intake compared to AM was also evident during NRD, as well (43.95% vs 12.28%, respectively).As previously demonstrated [11], Athonian fasting is characterized by a remarkable restraint of total fat intake, compared to the traditional MD pattern followed by the general population included in this analysis, which comprises a 37-40% 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 (MUFA) and *n*-6 and *n*-3 polyunsaturated fatty acids (PUFA). 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 *n*-3 PUFA 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 Mediterranean and Western diets, not only regarding the quantity and sources of MUFA, but also in the quantity of *n*-6 and *n*-3PUFA. Results of the PREDIMED trial [36] demonstrated that a typical MD - although of relatively high fat intake (35–40%) compared to the nutritional model suggested from 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 favour higher consumption of refined starch-and sugar-rich foods, thus contributing to excessive energy intakes. In support of this concern, there is some evidence that both MUFA and PUFA in the Mediterranean eating pattern tend to reduce LDL-C and TG, while increasing HDL-C [11, 39].Moreover, with the exception of a 3-fold increase during NRD compared with RD in the general population, consumption of saturated fat was remarkably lower compared to typical Northern Europe and Western population eating patterns[35-37].

Lipid and glucose profiles were optimal for the majority of included subjects 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 favourable glucose homeostasis profile compared to general population fasters, 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 compared with lay people, using HOMA-IR [24]. Although fasting glucose concentrations were significantly lower in monks compared with lay fasters (4.71±0.60 vs 5.12±0.32 mmol/L respectively; $p<.001$), fasting insulin concentrations were almost threefold lower in monks (4.61±3.16 vs 11.64±9.21 μg/ml respectively; $p<.001$). Fasting insulin levels have been shown to highly correlate with HOMA-IR measurements [41]. This lower insulin resistance in the monks is highly favourable, since insulin resistance has been proposed as a central mediator of several non-communicable diseases characterised by chronic inflammation [42-46]. The lower insulin resistance seen in the monks is likely to relate to their lower BMI, BF and VF compared with the lay sample (**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 visceral fat 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 impact on clinical outcomes such as Alzheimer's disease, diabetes, cardiovascular disease 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 impact on their vitamin D status. Comparable findings have been previously reported in other populations of the Mediterranean region, in whom, cutaneous vitamin D production is affected by clothing preference [51,52].

Our study presents specific limitations. The number of included subjects was relatively small; however, we consider that it was representative, since 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 unable to establish causal associations.

In 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 impact 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 caloric 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 being free of genetically modified ingredients. Future trials are necessary in order 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.

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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	p=.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	p<.001
Height (cm)	178.07 ± 6.24	176.69 ± 3.25	p=.160
BMI	28.92 ± 4.50	23.77 ± 3.91	p<.001
BF (%)	26.04 ± 8.18	18.33 ± 8.34	p<.001
BF (kg)	24.61 ± 11.18	14.57 ± 8.98	p=.001
VF (kg)	13.49 ± 5.87	7.08 ± 4.50	p<.001
WC (cm)	94.32 ± 3.32	83.26 ± 4.23	p<.001
FFM (kg)	66.63 ± 5.50	59.76 ± 6.07	p<.001
MM (kg)	59.38 ± 5.30	33.31 ± 4.54	p<.001
TBW %	54.24 ± 6.01	60.01 ±6.21	p<.001
TBW kg	48.87 ± 3.99	43.94 ± 4.41	p<.001
BMR kcal	1810.09 ±118.59	1661.88 ± 131.07	p<.001

Abbreviations: y: years; kg: kilograms; cm: centimetres; BMI: Body Mass Index; BF: Body fat; VF: Visceral fat; WC: Waist Circumference; FFM: Fat-free mass; MM: Muscle mass; TBW: Total body water; BMR: Basal metabolic rate

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

Intake	Restrictive Day (RD)	Non-Restrictive Day (NRD)	Test Statistics
Energy (kcal)	1575.5 ± 285.96	2137.8 ± 470.84	t(23)= -6.657, d = -1.473, r= 0.491, p < .001
Carbohydrates (g)	235.20 ± 71.49	176.94 ± 51.19	t(23)= 3.339, d = 0.688, r = 0.047, p= .003
%TEI	59.9 ± 14.4	32.97 ± 6.24	Z = -4.229, p < .001
Fat (g)	54.94 ± 26.92	104.59 ± 31.22	t(23)= -5.985, d = -1.19, r = 0.028, p < .001
%TEI	31.0 ± 13.71	44.58 ± 9.23	Z = -3.029, p = .002
Protein (g)	48.58 ± 15.98	98.01 ± 21.81	t(23)= -10.008, d = -2.04, r = 0.209, p < .001
%TEI	12.4 ± 3.84	18.79 ± 4.63	Z = -4.143, p < .001
Saturated fat (g)	10.36 ± 8.13	34.97 ± 14.70	t(23)=-7.650, d = -1.628, r = 0.142, p < .001
Cholesterol (mg)	64.04 ± 145.90	372.21 ± 175.25	t(23)=-6.497, d = -1.331, r = -0.039, p<.001
Fiber (g)	38.74 ± 16.49	19.84 ± 10.87	t(23)=4.554, d = 0.946, r = -0.066, p < .001
Ca (mg)	484.69 ± 263.02	887.61 ± 411.14	t(23)=-3.667, d = -0.76, r = -0.238, p = .002
%DRI	48.47 ± 26.31	86.02 ± 41.30	Z = -3.072, p = .002
Fe (mg)	16.54 ± 6.02	13.45 ± 4.68	t(23)=1.822, d = 0.368, r = -0.193, p = .079
%DRI	165.43 ± 60.20	135.47 ± 46.99	Z = -1.642, p = .101
Mg (mg)	283.63 ± 130.77	240.90 ± 98.08	t(23)=1.367, d = 0.283, r = 0.127, p = .208
%DRI	67.53 ± 31.14	58.02 ± 22.97	Z = -1.095, p = .274
Na (mg)	1767.56 ± 1007.20	3224.33 ± 1184.78	t(23)=-4.113, d = -1.074, r = 0.234, p= .001
%DRI	73.65 ± 41.97	130.90 ± 51.88	Z = -3.102, p = .002
K (mg)	2575.82 ± 1065.56	2790.70 ± 982.00	t(23)=-0.841, d = -0.169, r = 0.231, p = .438
%DRI	68.59 ± 28.41	74.85 ± 25.77	Z = -0.639, p = .523
Vit A (mcg)	732.90 ± 817.94	1209.66 ± 1245.59	t(23)=-1.564, d = -2.435, r = 0.982, p = .162
%DRI	73.29 ± 81.80	121.81 ± 124.57	Z = -2.007, p = .045
Vit B12 (mcg)	1.06 ± 1.63	5.61 ± 4.95	t(23)=-5.165, d = -0.982, r = 0.008, p <.001
%DRI	44.36 ± 67.75	227.92 ± 211.26	Z = -3.848, p < .001
Vit B2 (mcg)	1.10 ± 0.38	1.75 ± 0.43	t(23)=-5.176, d = -1.420, r = 0.361, p <.001
%DRI	84.23 ± 29.01	132.92 ± 34.93	Z = -3.650, p < .001
Vit C (mcg)	119.88 ± 94.00	103.93 ± 94.74	t(23)=0.763, d = 0.112, r = 0.046, p = .523
%DRI	199.79 ± 156.66	173.41 ± 157.77	Z = -0.517, p = .605
Vit D (mcg)	0.60 ± 1.09	3.14 ± 3.82	t(23)=-3.057, d = -1.213, r = 0.636, p = .006
%DRI	11.97 ± 21.78	60.36 ± 77.38	Z = -3.255, p = .001
Vit E (mcg)	8.31 ± 4.45	9.16 ± 4.25	t(23)=-0.680, d = -0.606, r = 0.948, p = .551
%DRI	83.10 ± 44.56	92.09 ± 42.03	Z = -0.821, p = .412

Abbreviations: %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	Restrictive Day (RD)	Non-Restrictive Day (NRD)	Test Statistics
Energy (kcal)	1362.42 ± 84.52	1571.55 ± 81.07	t(69)= -24.146, d = -2.890, r = 0.618, p < .001
Carbohydrates (g)	159.6 ± 21.82	294.35 ± 23.40	t(69)= -54.777, d = -6.565, r = 0.588, p < .001
%TEI	46.64 ± 3.41	74.95 ± 2.43	Z = -7.300, p < .001
Fat (g)	30.07 ± 0.17	21.47 ± 1.96	t(69)= 37.412, d = 7.66, r = 0.396, p < .001
%TEI	19.93 ± 1.09	12.28 ± 0.63	Z = -7.300, p < .001
Protein (g)	89.24 ± 1.38	72.35 ± 1.32	t(69)= 119.795, d = 14.315, r = 0.618, p < .001
%TEI	26.28 ± 1.19	18.47 ± 0.56	Z = -7.300, p < .001
Saturated fat (g) [a,b]	12.75 ± 0.00	16.40 ± 0.00	-
Cholesterol (mg) [a,b]	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 < .001
Ca (mg)	579.51 ± 2.29	665.69 ± 2.27	t(69)= -2260.844, d = -267.274, r = 0.990, p < .001
%DRI	57.94 ± 0.23	66.56 ± 0.22	Z = -7.649, p < .001
Fe (mg)	13.70 ± 0.00	18.13 ± 0.06	t(69)= -619.482, p < .001
%DRI	137.00 ± 0.00	181.30 ± 0.60	Z = -7.722, p < .001
Mg (mg)	167.43 ± 3.29	152.29 ± 3.14	t(69)= 621.927, d = 105.300, r = 0.999, p < .001
%DRI	39.84 ± 0.77	36.23 ± 0.74	Z = -7.451, p < .001
Na (mg) [a,b]	1733.00 ± 0.00	1549.00 ± 0.00	-
%DRI [a,b]	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 < .001
%DRI	67.63 ± 2.34	100.07 ± 2.34	Z = -7.526, p < .001
Vit A (mcg)	805.64 ± 24.26	708.26 ± 24.46	t(69)= 1936.152, r = 1.00, p < .001
%DRI	80.48 ± 2.40	70.74 ± 2.42	Z = -7.414, p < .001
Vit B12 (mcg) [a,b]	5.50 ± 0.00	5.60 ± 0.00	-
%DRI [a,b]	229.17 ± 0.00	233.33 ± 0.00	-
Vit B2 (mcg)	1.01 ± 0.02	1.11 ± 0.02	t(69)= -99.901, d = -20.412, r = 0.970, p < .001
%DRI	77.44 ± 1.76	85.41 ± 1.26	Z = -7.475, p < .001
Vit C (mcg)	257.54 ± 2.99	373.78 ± 2.91	t(69)= -3868.426, d = -508.696, r = 0.997, p < .001
%DRI	429.04 ± 622.79	622.79 ± 4.79	Z = -7.507, p < .001
Vit D (mcg) [a,b]	1.00 ± 0.00	0.98 ± 0.00	-
%DRI [a,b]	20.00 ± 0.00	19.60 ± 0.00	-
Vit E (mcg) [a,b]	5.70 ± 0.00	13.80 ± 0.00	-
%DRI [a,b]	57.00 ± 0.00	138.00 ± 0.00	-

[a] 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). [b] Effect size cannot be calculated because of the uniform s.d. and/or perfect correlation.

Abbreviations: %DRI, percentage of the dietary reference intake; %TEI, percentage of the daily total energy intake

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 < .001
Carbohydrates (g)	235.20 ± 71.49	159.60 ± 21.82	t(92)= 7.905, d = 1.620, p < .001
%TEI	60.3 ± 18.5	46.64 ± 3.41	Z = -4.792, p < .001
Fat (g)	54.94 ± 26.92	30.07 ± 0.18	t(92)= 7.809, d = 1.835, p < .001
%TEI	30.5 ± 15.0	19.93 ± 1.09	Z = -3.634, p < .001
Protein (g)	48.58 ± 15.99	89.24 ± 1.38	t(92)= -21.268, d = -4.682, p < .001
%TEI	12.5 ± 4.1	26.28 ± 1.19	Z = -7.224, p < .001
Saturated fat (g)	10.36 ± 8.13	12.75 ± 0.00	t(92)= -2.484, d = -0.294, p = .015
Cholesterol (mg)	64.04 ± 145.90	181.00 ± 0.00	t(92)= -6.778, d = -0.802, p < .001
Fiber (g)	38.74 ± 16.49	23.42 ± 0.93	t(92)= 7.818, d = 1.759, p < .001
Ca (mg)	484.69 ± 263.02	579.51 ± 2.29	t(92)= -3.048, d = -0.715, p = .003
%DRI	48.60 ± 26.88	57.94 ± 0.23	Z = -4.088, p < .001
Fe (mg)	16.53 ± 6.02	13.7 ± 0.00	t(92)= 3.993, d = 0.470, p < .001
%DRI	167.30 ± 60.84	137.00 ± 0.00	Z = -4.527, p < .001
Mg (mg)	283.63 ± 130.77	167.43 ± 3.29	t(92)= 7.506, d = 1.734, p < .001
%DRI	67.34 ± 31.82	39.84 ± 0.77	Z = -4.303, p < .001
Na (mg)	1767.56 ± 1007.20	1733.00 ± 0.00	t(92)= 0.290, d = 0.034, p = .772
%DRI	74.91 ± 42.78	72.21 ± 0.00	Z = -0.412, p = .524
K (mg)	2575.82 ± 1065.56	2539.00 ± 88.56	t(92)= 0.289, d = 0.064, p = .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 = .455
%DRI	75.13 ± 83.12	80.48 ± 2.40	Z = -0.702, p = .004
Vit B12 (mcg)	1.06 ± 1.63	5.50 ± 0.00	t(92)= -23.064, d = -2.724, p < .001
%DRI	45.33 ± 69.10	229.17 ± 0.00	Z = -8.642, p < .001
Vit B2 (mcg)	1.10 ± 0.38	1.01 ± 0.02	t(92)= 1.949, d = 0.450, p = .054
%DRI	85.25 ± 29.22	77.44 ± 1.76	Z = -0.709, p = .478
Vit C (mcg)	119.88 ± 94.00	257.54 ± 2.99	t(92)= -12.364, d = -2.839, p < .001
%DRI	200.33 ± 160.16	429.04 ± 4.95	Z = -6.010, p < .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 < .001
Vit E (mcg)	8.31 ± 4.45	5.71 ± 0.30	t(92)= 4.914, d = 1.095, p < .001
%DRI	80.77 ± 43.93	57.00 ± 3.00	Z = -3.135, p = .002

Abbreviations: %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 Non-restrictive 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 < .001
Carbohydrates (g)	176.63 ± 51.19	294.35 ± 23.40	t(92)= -15.243, d = -3.156, p < .001
%TEI	33.39 ± 6.03	74.95 ± 2.43	Z = -7.236, p < .001
Fat (g)	104.59 ± 31.22	21.47 ± 1.96	t(92)= 22.378, d = 5.010, p < .001
%TEI	43.95 ± 9.27	12.28 ± 0.63	Z = -7.236, p < .001
Protein (g)	98.01 ± 21.81	72.35 ± 1.32	t(92)= 9.894, d = 2.219, p < .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 < .001
Cholesterol (mg)	372.21 ± 175.25	178.00 ± 0.00	t(92)= 9.370, d = 1.108, p < .001
Fiber (g)	19.84 ± 10.87	36.22 ± 0.89	t(92)= -12.617, d = -2.786, p < .001
Ca (mg)	887.61 ± 411.14	665.69 ± 2.27	t(92)= 4.564, d = 1.074, p < .001
%DRI	85.82 ± 42.22	66.56 ± 0.22	Z = -3.045, p = .002
Fe (mg)	13.45 ± 4.68	18.13 ± 0.06	t(92)= -8.442, d = -1.975, p < .001
%DRI	135.83 ± 48.02	181.30 ± 0.60	Z = -5.914, p < .001
Mg (mg)	240.92 ± 98.08	152.29 ± 3.14	t(92)= 7.627, d = 1.751, p < .001
%DRI	57.94 ± 23.48	36.23 ± 0.74	Z = 5.345, p < .001
Na (mg)	3224.33 ± 1184.78	1549.00 ± 0.00	t(92)= 11.956, d = 1.414, p < .001
%DRI	131.04 ± 53.04	64.54 ± 0.00	Z = -6.996, p < .001
K (mg)	2790.70 ± 982.00	3755.59 ± 88.87	t(92)= -8.208, d = -1.802, p < .001
%DRI	75.16 ± 26.30	100.07 ± 2.34	Z = -5.435, p < .001
Vit A (mcg)	1209.66 ± 1245.59	708.26 ± 24.46	t(92)= 3.402, d = 0.790, p = .001
%DRI	122.04 ± 127.47	70.74 ± 2.42	Z = -2.134, p = .033
Vit B12 (mcg)	5.62 ± 4.95	5.60 ± 0.00	t(92)= 0.029, d = 0.004, p = .977
%DRI	231.18 ± 215.18	233.33 ± 0.00	Z = -2.058, p = .040
Vit B2 (mcg)	1.75 ± 0.43	1.11 ± 0.02	t(92)= 12.656, d = 2.844, p < .001
%DRI	133.11 ± 35.71	85.41 ± 1.26	Z = -6.052, p < .001
Vit C (mcg)	103.93 ± 94.74	373.78 ± 2.91	t(92)= -24.048, d = -5.527, p < .001
%DRI	176.98 ± 160.32	622.78 ± 4.79	Z = -7.232, p < .001
Vit D (mcg)	3.14 ± 3.82	0.98 ± 0.00	t(92)= 4.787, d = 0.565, p < .001
%DRI	62.33 ± 78.50	19.60 ± 0.00	Z = -3.704, p < .001
Vit E (mcg)	9.16 ± 4.25	13.81 ± 0.30	t(92)= -9.191, d = -2.044, p < .001
%DRI	89.18 ± 40.43	138.00 ± 3.00	Z = -4.707, p < .001

Abbreviations: %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 = .470
TRIG (mg/dl)	113.22 ± 79.09	73.82 ± 31.68	t(105)= 3.460, d = 0.711, p = .001
HDL (mg/dl)	43.20 ± 11.05	47.83 ± 14.11	t(103.733)= -1.898, d = -0.368, p = .061
LDL (mg/dl)	120.68 ± 45.92	119.97 ± 36.70	t(93.582)= 0.088, d = 0.017, p = .930
Calcium (mg/dl)	9.01 ± 1.27	9.06 ± 0.42	t(112)= -0.270, d = -0.059, p = .788
Phosphor (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 < .001
PTH (pg/ml)	37.69 ± 16.36	116.09 ± 49.75	t(110)= -11.283, d = -2.372, p < .001
1250H2D2	27.93 ± 36.00	-	-
1a250H2D3	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 = .001
Glucose (mmol/l)	5.12 ± 0.32	4.71 ± 0.60	t(114)= 4.645, d = 0.891, p <.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 < .001
Ferritin (ng/ml)	-	77.65 ± 37.92	-

Abbreviations: CRP: C-Reactive protein; ALT: alanine transaminase; AST: aspartate transaminase; CHOL: total cholesterol; HDL: high-density lipoprotein cholesterol; LDL: low-density lipoprotein cholesterol; PTH: parathyroid hormone; TRIG: triglycerides; 25(OH)D: 25-hydroxyvitamin-D; HOMA-IR: Homeostatic Model Assessment for Insulin Resistance