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ORIGINAL PAPER

# Effect of periodic abstinence from dairy products for approximately half of the year on bone health in adults following the Christian Orthodox Church fasting rules for decades

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## Abstract

**Summary** Christian Orthodox Church (COC) fasting is characterized by periodic abstinence from animal foods (including dairy products). We found that, despite this, older individuals adhering to COC fasting for decades did not differ in bone mineral density, bone mineral content, or prevalence of osteoporosis at five sites from non-fasting controls.

**Purpose** The present observational study investigated whether adherence to COC fasting, characterized by periodic abstinence from animal foods (including dairy products), affects bone health and the prevalence of osteoporosis in older individuals.

**Methods** Participants were 200 men and women, of whom 100 had been following the fasting rules of the COC for a median of 31 years and 100 were non-fasters, all aged 50 to 78 years. Participants underwent measurements of bone mineral density (BMD) and bone mineral content (BMC) at the lumbar spine, right hip, left hip, right femoral neck, and left femoral neck; completed a 3-day food intake record and food frequency questionnaire; and provided blood samples for biochemical measurements.

**Results** Fasters did not differ from non-fasters in demographic characteristics, anthropometric measures, BMD, BMC, or prevalence of osteopenia or osteoporosis at any of the five sites measured ($P > 0.05$). Fasters had lower daily calcium intake than non-fasters (median 532 vs 659 mg, $P = 0.010$), daily protein intake (0.67 vs 0.71 g/kg, $P = 0.028$), and consumption of dairy and soy products (10.3 vs 15.3 servings per week, $P < 0.001$). Groups did not differ in serum calcium, vitamin D, or urea concentrations.

**Conclusions** Despite lower calcium intake and lower consumption of dairy and soy products, older individuals adhering to COC fasting did not differ in BMD, BMC, or prevalence of osteoporosis from controls. Thus, periodic abstinence from dairy and, generally, animal products does not seem to compromise bone health in older individuals.

**Keywords** Bone mineral density · Calcium · Christian Orthodox Church fasting · Dairy · Osteoporosis · Vitamin D

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s11657-019-0625-y) contains supplementary material, which is available to authorized users.

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## Introduction

Osteoporosis is a systemic skeletal disease characterized by low bone mass and deterioration of bone microarchitecture, with consequent increased bone fragility and susceptibility to fracture [1]. Osteoporosis is a major public health concern, affecting 200 million worldwide [2] and causing 9 million fractures per year, which are accompanied by substantial pain and suffering, impaired quality of life, disability, and even death [3]. Since it is a disease associated primarily with old age, its prevalence is expected to rise with improvements in life expectancy.

Although genetic and hormonal factors influence skeletal health, proper nutrition is considered essential for the prevention of osteoporosis [4]. In this context, dietary lifestyles that are biased toward specific food sources and/or exclude other food sources offer the opportunity to examine the dependence of bone health on nutrition. One such case is the lifelong periodic fasting implemented by the Christian Orthodox Church (COC).

In COC lifestyle, faith is expressed, among other things, through abstinence from certain foods—predominantly of animal origin except for seafood and snails—for certain periods and days during the year. The total days of COC fasting range from 159 to 197 (average, 178) and include five main periods, three important religious days, Wednesdays, and Fridays, as detailed in Supplemental Table 1. However, to facilitate replenishment of nutrients in the body after prolonged fasting, the COC has set two periods, comprising a total of 47 days, of no food restriction (not even on Wednesdays or Fridays).

A fundamental characteristic of COC fasting rules is the avoidance of meat, poultry, eggs, and dairy products. Consumption of olive oil, wine, and fish is generally permitted during fasting, except on Wednesdays and Fridays, unless these fall on the 47 days during which there is no food restriction. Seafood, such as oysters, mussels, shrimp, cuttlefish, octopus, squid, crab, and lobster, as well as snails, are permitted during all fasting days on which oil consumption is allowed. These characteristics of COC fasting are reminiscent of the Mediterranean diet [5].

At the same time, the characteristics of COC fasting raise concern about possible consequences on bone health. In particular, the exclusion of dairy products (the best source of calcium) and eggs (a good source of cholecalciferol) from the diet during approximately half of the year, as well as the abstention from fish (another good source of cholecalciferol) during approximately 5 months, may compromise calcium status in the body [6]. Therefore, the present study sought to investigate the role of COC fasting on bone mass maintenance and prevalence of osteoporosis among men and women above 50 years of age. To the best of our knowledge, there are no other studies assessing the potential impact of so long periodic abstinence from dairy products on bone health or osteoporosis.

## Methods

### Participants and study period

This study is part of a larger cross-sectional study aimed at investigating the effects of COC fasting on health (including bone health) by comparing fasting to non-fasting individuals (hereafter referred to as fasters and non-fasters). Because, as mentioned, we are unaware of any similar study, we could not perform a power analysis to determine the necessary sample size. Thus, we intuitively chose to recruit at least 400 adults, equally divided between fasters and non-fasters. This number is much higher than the sample sizes of 120 and 59 in two previous studies that examined the association of COC fasting with serum lipids and obesity [7] and with iron status [8], respectively.

We further decided to divide our sample equally between the ages of $< 50$ and $\geq 50$, with at least 100 fasters and 100 non-fasters in each age group. The present study focuses on the older group; the sample sizes comply with the estimate of Ho-Pham and coworkers [9] that a sample size of 91 vegetarians and 91 omnivores was required to have a power of 0.80 in detecting a difference of 0.05 g/cm$^2$ in bone mineral density (BMD) at the confidence interval of 95%. Although COC fasters are not vegetarians, the aforementioned study was as close to our study as we could possibly find.

Participants were recruited on a voluntary basis in the province of Thessaloniki, Greece, between September 2013 and October 2015 through churches, a monastery, and public centers for the elderly. Of the 218 individuals who consented to participate, 15 were excluded because they did not meet the inclusion criteria, which were the absence of chronic disease, absence of morbid obesity (BMI $\geq$ 40 kg/m$^2$), no dietary supplementation, no medication, and (in the case of the fasting group) adherence to COC fasting for at least 10 years. Three more individuals were excluded because they did not complete all measurements. The remaining 200 participants were 100 fasters and 100 non-fasters. The fasters included 68 women and 32 men; the non-fasters included 66 women and 34 men.

To ensure that the data regarding the fasters were as representative of the entire year as possible, we did not perform measurements during periods of fasting or periods of no food restriction. Rather, all measurements and blood sampling were performed on Saturdays during the periods characterized by fasting on Wednesdays and Fridays only.

## Anthropometric and cardiac parameters

Body weight was measured on a digital scale to the nearest 0.1 kg with the participant wearing light clothing and no shoes. Standing height was measured with a portable stadiometer to the nearest centimeter. Resting heart rate and blood pressure were measured with an electronic blood pressure monitor (Omron, Hoffman Estates, IL) in sitting position after 10 min of rest.

## Bone health parameters

BMD and bone mineral content (BMC) were evaluated using dual-energy X-ray absorptiometry (Lunar DPX Bravo, GE Healthcare, equipped with the GE Lunar enCORE software, v. 13.5) at the lumbar spine (L2–L4), right hip, left hip, right femoral neck, and left femoral neck. Osteoporosis was diagnosed as BMD of 2.5 standard deviations (*T* score) or more below the young adult reference mean, whereas osteopenia was defined as a *T* score between − 1.0 and − 2.5 [10]. Participants were also asked about any history of bone fracture.

## Biochemical parameters

Six milliliters of blood was drawn from a forearm vein in sitting position between 8 and 10 a.m., after 12 h of fast. Blood samples were placed in test tubes without anticoagulant, left to clot at room temperature, and centrifuged at 1500*g* for 10 min. Serum was separated from other blood components, divided into Eppendorf tubes, and stored at − 80 °C until analyzed for calcium, vitamin D (specifically, 25-hydroxyvitamin D), and urea (as an index of protein intake). Calcium was measured through the arsenazo III method in a Mindray BS-300 Chemistry Analyzer. Vitamin D was measured through chemiluminescent microparticle immunoassay in an Abbott Architect i2000SR analyzer. Urea was measured through the urease–glutamate dehydrogenase method in a Mindray BS-300 Chemistry Analyzer. The coefficients of variation for the three analytes were 5%, 7%, and 3%, respectively, and the laboratory carrying out these measures was involved in a nationwide external quality control program.

## Dietary assessment

Dietary calcium, vitamin D, protein, and alcohol intakes were assessed through interviewer-based recalls of food intake over 3 days, which included a Wednesday or Friday (during which the fasters obeyed fasting), another weekday, and a weekend day. Participants were interviewed about all foods and liquids consumed during those days. Food intake records were analyzed using the Food Processor Nutrition Analysis software (ESHA, Salem, OR).

In addition to the food intake records, a semi-quantitative food frequency questionnaire with 140 questions was used to assess the participants' dietary habits during a period of 1 month. Frequency of consumption was based on a typical portion of each food and beverage. This questionnaire was then used to assess the consumption of dairy products (milk, yogurt, cheese, butter, and dairy cream) and soy products (soy milk and soy cheese) as good sources of calcium. Soy products were included to take into account 20 participants, 17 fasters and 3 non-fasters, who obtained part of their calcium intake from them. The questionnaire was also used to evaluate adherence to the Mediterranean diet through the MedDietScore [11], an 11-item index that produces a score ranging from 0 to 55 (0 to 5 for each item); a higher score suggests a greater adherence to the traditional Mediterranean diet.

## Physical activity and smoking habits

Participants were asked to rank their habitual physical activity as very low, low, moderate, high, or very high on a 5-point scale. Additionally, they were asked what type of physical activity they practiced for distinction of those who practiced high-intensity/impact weight-bearing exercise from those who did not. Finally, they were asked about their smoking habits. Those who smoked one or more cigarettes per day were classified as smokers.

## Ethics

The study protocol was approved by the Bioethics Committee of the Alexander Technological Educational Institute of Thessaloniki, and the study was conducted according to the Declaration of the World Medical Association of Helsinki (1989). Each participant was informed about the aims, benefits, and potential risks of the study and signed a consent form before data collection and blood sampling.

## Statistical analysis

The Kolmogorov–Smirnov test and histogram charts were used to assess the normality of distribution of continuous variables. The distribution of most variables differed significantly from normal in at least one of the two groups (fasters or non-fasters). Thus, for the sake of uniformity, we report all continuous variables as median (interquartile range) and compared groups by using the non-parametric Mann–Whitney *U* test throughout. The few variables that warranted a *t* test did not produce a different outcome from the Mann–Whitney *U* test. Nominal variables are reported as percentages and were tested through the $\chi^2$ test.

Statistical analysis was performed using the SPSS, version 25 (SPSS, Chicago, IL). All statistical tests and corresponding

$P$ values were two-sided, and the level of statistical significance was set at 0.05.

## Results

### Demographic characteristics

Fasters were 58.2 (54.0–62.3) years old (maximum 77.6) and had been observing COC fasting for 31 (10–63) years, starting at the age of 25 (20–46). Fourteen had started fasting before adulthood (between the ages of 10 and 15). Non-fasters were 56.4 (53.2–61.8) years old (maximum 77.3). All women were postmenopausal, with menopause having occurred at the age of 50 (45–52) in fasters and 49 (47–50) in non-fasters. The two groups did not differ in any of the aforementioned parameters ($P > 0.05$).

### Anthropometric and cardiac parameters

Body weight, height, BMI, resting heart rate, systolic blood pressure, and diastolic blood pressure of the participants are shown in Table 1. The two groups did not differ in any anthropometric or cardiac parameter ($P > 0.05$) except for diastolic blood pressure ($P = 0.007$), which was thus more favorable in fasters.

### Bone health parameters

The two groups did not differ significantly in BMD (Fig. 1) or BMC (Fig. 2) at the lumbar spine, right hip, left hip, right femoral neck, or left femoral neck. Likewise, the 14 fasters who started fasting before adulthood did not differ significantly from the 86 who started as adults in any of these parameters. The frequency of osteoporosis and osteopenia at these sites (Table 2) was independent of group ($P > 0.05$), as shown by $\chi^2$ tests where all expected frequencies were at least 5% to ensure validity. Likewise, the frequency of osteoporosis and osteopenia was independent of sex. The average prevalence of osteoporosis was 5% (ranging from 0 to 16% across sites, groups, and sexes), while the average prevalence of osteopenia was 35% (ranging from 22 to 50%). Eighty-eight fasters and 82 non-fasters were free of osteoporosis at all five sites, although this difference was not statistically significant. Twenty participants from each group, all women, had had bone fractures.

### Biochemical and dietary parameters

The serum calcium, 25-hydroxyvitamin D, and urea concentrations are shown in Table 3. The two groups did not differ significantly in calcium or vitamin D, whereas the difference in urea was marginally significant ($P = 0.095$). Daily dietary calcium, vitamin D, and protein intakes, based on the 3-day recalls, are also shown in Table 3. The differences in calcium and protein intake were significant ($P = 0.010$ and 0.028, respectively).

The lower calcium intake of fasters compared to non-fasters was corroborated by the analysis of the food frequency questionnaire: fasters consumed 10.3 (7.6–16.3) servings of dairy and soy products per week, whereas non-fasters consumed 15.3 (10.6–21.0) servings ($P < 0.001$). Finally, the corresponding MedDietScore was the same for the two groups: 30 (27–34) and 30 (27–33), respectively. Daily alcohol consumption was 0 (0–0) g in both groups, since most participants (89 fasters and 76 non-fasters) reported none.

### Physical activity and smoking habits

Fasters did not differ from non-fasters in habitual physical activity (Fig. 3). Only seven fasters and eight non-fasters practiced high-intensity/impact weight-bearing exercises. Fasters smoked considerably less than non-fasters, since only three fasters were smokers, as compared to 36 non-fasters ($P < 0.001$). Fasters smoked 0 (0–0) cigarettes daily, whereas non-fasters smoked 0 (0–5) cigarettes daily.

**Table 1** Demographic, anthropometric, and cardiac parameters of the participants (median and interquartile range)

| Parameter | Fasters ($n = 100$) | Non-fasters ($n = 100$) |
|---|---|---|
| Gender (female/male) | 68/32 | 66/34 |
| Age (years) | 58.2 (54.0–62.3) | 56.4 (53.2–61.8) |
| Body weight (kg) | 75.5 (68.8–84.0) | 76.7 (66.5–84.3) |
| Height (m) | 1.63 (1.58–1.69) | 1.63 (1.59–1.71) |
| BMI (kg/m$^2$) | 28.0 (25.8–31.4) | 28.1 (25.0–30.5) |
| Resting heart rate (bpm) | 69 (62–76) | 70 (64–76) |
| Systolic blood pressure (mmHg) | 130 (123–133) | 129 (126–133) |
| Diastolic blood pressure (mmHg) | 80 (74–84) | 82 (78–85)* |

*$P = 0.007$, significantly different from fasters according to Mann–Whitney $U$ test

## Discussion

In the present study, we have examined differences in a number of parameters related to bone health (specifically, BMD, BMC, prevalence of osteopenia and osteoporosis, and history of bone fracture) between individuals of both sexes, aged 50 to 78 years, who had been adhering to periodic fasting according to the rules of the COC for at least 10 years and controls who did not restrict their diet. Our main finding is that bone health did not differ between groups even though fasters had lower consumption of dairy and soy products, as well as lower calcium and protein intakes (but not lower food consumption overall, as evidenced by the absence of difference in BMI). Although previous studies [7, 8] have addressed the impact of COC fasting on health indices (specifically, the lipidemic profile, BMI, and iron status), this is the first study, to the best of our knowledge, relating COC fasting to the prevalence of chronic diseases such as osteoporosis.

Sufficient consumption of dairy products is generally recommended due their high contents of high-quality protein, minerals, and vitamins, with most countries suggesting 2 to 3 servings per day for the adult population [12]. In our study, consumption of dairy and soy products was below these recommendations for most fasters: division of the weekly intakes by 7 yielded 1.5 (1.1–2.3) servings per day for fasters and 2.2 (1.5–3.0) servings per day for non-fasters. Yet, fasters did not differ from non-fasters in any of the bone health parameters assessed. These findings challenge the view that dairy consumption is beneficial for bone health and constitute a useful addition to recent controversial findings showing an association of higher milk and total dairy consumption with a lower risk of hip fracture in older adults [13], no clear association of milk or total dairy consumption with the risk of hip fracture [14], and an attenuation of age-related cortical bone loss in consumers of fermented dairy products (such as yogurt) but not in consumers of milk or ripened cheese [15]. It is thus possible that bone health depends on other factors than the intermittent intake of specific foods.

A recent meta-analysis has concluded that, compared with omnivores, vegetarians and vegans have lower BMD at the femoral neck and lumbar spine, while vegans have higher fracture rates [16]. These conclusions, combined with the findings of the present study, suggest that, although abolition of many or all foods of animal origin for life (vegetarianism and veganism, respectively) is detrimental to bone health, periodic abstinence from these foods for about half of the year (COC fasting) does not.

In accordance with the lower consumption of dairy and soy products, calcium intake by fasters was lower than that by non-fasters. Nevertheless, most fasters obtained more calcium (median 532 mg/day) than the recommended minimum of 400–500 mg/day for the prevention of osteoporosis [17]. This may explain the fact that fasters did not differ from non-fasters in BMD, BMC, or fracture

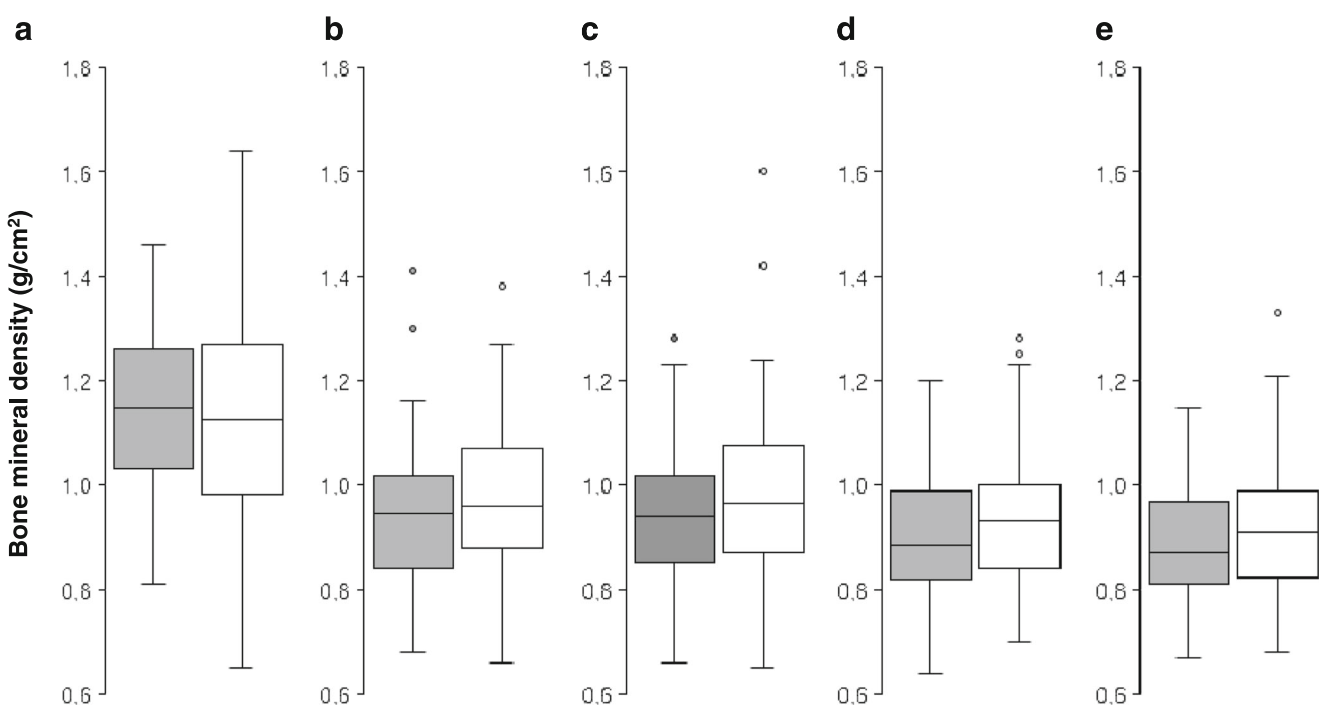


**Fig. 1** Box plots of bone mineral density at the lumbar spine (**a**), right hip (**b**), left hip (**c**), right femoral neck (**d**), and left femoral neck (**e**) of fasters (gray boxes) and non-fasters. Each box represents the interquartile range, and the center line represents the median. Whiskers are extended to the most extreme data point that is no more than 1.5 times the interquartile range from the edge of the box (Tukey style). Dots represent outliers. No significant difference between groups was found (Mann–Whitney *U* test, $P > 0.05$).

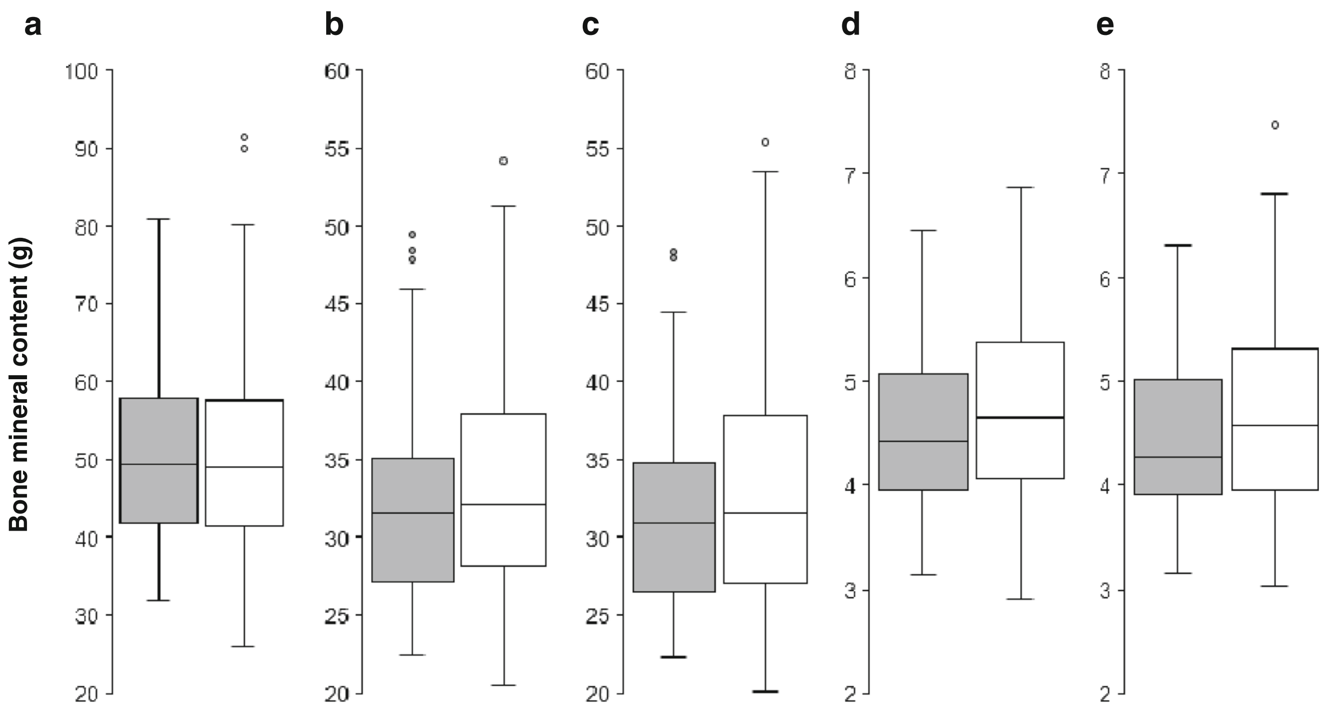


**Fig. 2** Box plots of bone mineral content at the lumbar spine (**a**), right hip (**b**), left hip (**c**), right femoral neck (**d**), and left femoral neck (**e**) of fasters (gray boxes) and non-fasters. See Fig. 1 for description of each plot's

rate. Considering the fact that the DRI for calcium for older adults is 1000–1200 mg [18], our findings suggest that not as much calcium is needed to optimize BMD and BMC and prevent osteoporosis.

In addition to calcium, fasters had lower intakes of two more nutrients related to bone health, that is, vitamin D and protein [19–21], although the difference in vitamin D did not reach statistical significance, despite being numerically large (due to the wide dispersion of the individual values), and although sunshine exposure is usually the most important determinant of circulating 25-hydroxyvitamin D levels. These findings can also be explained by the lower consumption of dairy products and, generally, foods of animal origin by fasters. As with calcium, however, these lower intakes were not reflected in did not prove enough to cause a difference between fasters and non-fasters in the bone health parameters assessed in this study.

Despite a significant difference in dietary calcium intake, the serum calcium concentration did not differ between fasters and non-fasters. This may be explained by the presence of a very efficient calcium homeostatic system in the body [22]. Likewise, despite a significant difference in dietary protein intake, the serum urea concentration did not differ between fasters and non-fasters. However, differences in both parameters were numerically small (6 to 10%) and in the same direction (that is, both protein intake and serum urea concentration were higher in the non-fasters). Finally, the serum vitamin D concentration and vitamin D intake did not differ significantly between groups and were numerically higher in non-fasters. In all, the biochemical data seem to be in accordance with the dietary ones.

An interesting finding of our study was the lower diastolic blood pressure of fasters compared to non-fasters. This suggests that some aspect of their lifestyle is more favorable. At

**Table 2** Prevalence of osteoporosis and osteopenia at five sites

| Site | Osteoporosis (%) | | Osteopenia (%) | | Normal (%) | |
|---|---|---|---|---|---|---|
| | Fasters | Non-fasters | Fasters | Non-fasters | Fasters | Non-fasters |
| Lumbar spine | 6 | 15 | 28 | 31 | 66 | 54 |
| Right hip | 3 | 3 | 38 | 28 | 59 | 69 |
| Left hip | 3 | 2 | 35 | 30 | 62 | 68 |
| Right femoral neck | 7 | 1 | 39 | 33 | 54 | 66 |
| Left femoral neck | 5 | 1 | 47 | 43 | 48 | 56 |

**Table 3** Biochemical and dietary parameters of the participants (median and interquartile range)

| Parameter | Fasters ($n = 100$) | Non-fasters ($n = 100$) |
|---|---|---|
| Serum calcium (mg/dL) | 9.7 (9.4–10.1) | 9.7 (9.4–9.9) |
| Serum 25-hydroxyvitamin D (ng/mL) | 16.5 (12.7–20.8) | 18.2 (12.7–23.2) |
| Serum urea (mg/dL) | 29 (24–36) | 32 (25–40) |
| Daily dietary calcium intake (mg) | 532 (347–752) | 659 (474–857)* |
| Daily dietary vitamin D intake (μg) | 1.20 (0.41–2.79) | 1.69 (0.65–3.30) |
| Daily dietary protein intake (g) | 0.67 (0.46–0.84) | 0.71 (0.58–0.93)* |

*$P < 0.05$, significantly different from fasters according to Mann–Whitney $U$ test

present, it is not clear what that aspect might be. Further analyses are under way, which might shed light on this difference.

A limitation of the present study is the one always associated with studies involving self-reporting of lifestyle parameters. Therefore, the possibility exists of misreporting (either under- or over-reporting) food intakes, physical activity, and smoking habits. However, there is no reason to suspect that fasters misreported these parameters in a way different from non-fasters. Additionally, because of the variation in dietary habits of fasters over the year, the possibility exists that some of the measured endpoints may fluctuate depending on when they are measured (although it is difficult to think that the primary endpoints, such as BMD, BMC, and prevalence of osteopenia and osteoporosis, can fluctuate during a year). Nevertheless, it would be desirable to perform the same measurements in future studies during periods of fasting and periods of no food restriction in addition to the "intermediate" period assessed in the present study.

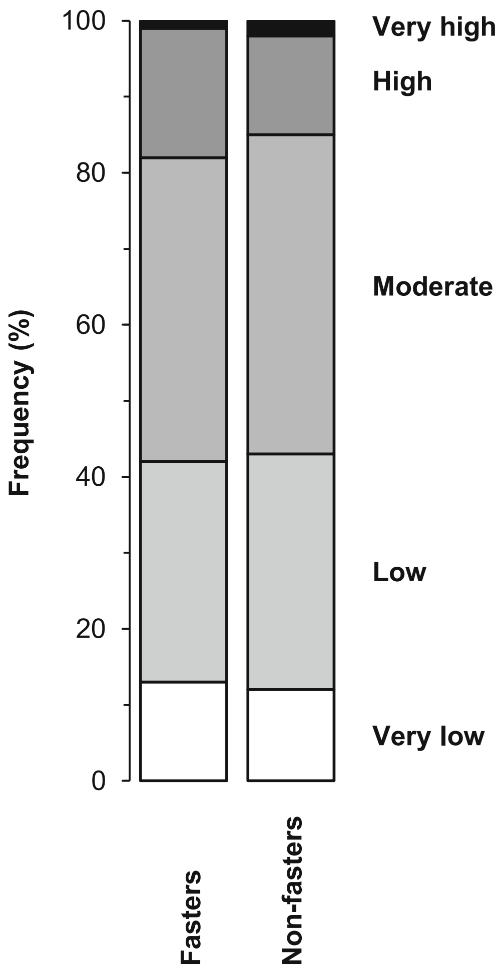


**Fig. 3** Distribution of physical activity levels in fasters and non-fasters. Groups did not differ significantly ($\chi^2$ test, $P > 0.05$).

In conclusion, despite lower calcium intake and lower consumption of dairy and soy products, older men and women adhering to COC fasting did not differ from peers who did not fast in any of the indices of bone health examined. Thus, periodic abstinence from dairy and, in general, animal products does not seem to harm bone health in older individuals. This finding may prove useful in designing healthy diets for people who wish, or need, to have limited intake of such foods.

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## Compliance with ethical standards

**Ethics** The study protocol was approved by the Bioethics Committee of the Alexander Technological Educational Institute of Thessaloniki, and the study was conducted according to the Declaration of the World Medical Association of Helsinki (1989). Each participant was informed about the aims, benefits, and potential risks of the study and signed a consent form before data collection and blood sampling.

**Conflicts of interest** None.

## References

1. Pisani P, Renna MD, Conversano F, Casciaro E, Di Paola M, Quarta E, Muratore M, Casciaro S (2016) Major osteoporotic fragility

fractures: risk factor updates and societal impact. World J Orthop 7: 171–181
2. Lin JT, Lane JM (2004) Osteoporosis—a review. Clin Orthop Relat Res 425:126–134
3. Johnell O, Kanis JA (2006) An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. Osteoporos Int 17:1726–1733
4. Kruger MC, Wolber FM (2016) Osteoporosis: modern paradigms for last century's bones. Nutrients. 8:376
5. Sarri KO, Linardakis MK, Bervanaki FN, Tzanakis NE, Kafatos AG (2004) Greek Orthodox fasting rituals: a hidden characteristic of the Mediterranean diet of Crete. Br J Nutr Aristotle University of Thessaloniki 92:277–284
6. Papadaki A, Vardavas C, Hatzis C, Kafatos A (2008) Calcium, nutrient and food intake of Greek Orthodox Christian monks during a fasting and non-fasting week. Public Health Nutr 11:1022–1029
7. Sarri KO, Tzanakis NE, Linardakis MK, Mamalakis GD, Kafatos AG (2003) Effects of Greek orthodox Christian church fasting on serum lipids and obesity. BMC Public Health 3:16
8. Sarri KO, Kafatos AG, Higgins S (2005) Is religious fasting related to iron status in Greek Orthodox Christians? Br J Nutr 94:198–203
9. Ho-Pham L, Nguyen P, Le T, Doan T, Tran N, Le T, Nguyen T (2009) Veganism, bone mineral density, and body composition: a study in Buddhist nuns. Osteoporos Int 20:2087–2093
10. WHO (2004) WHO scientific group on the assessment of osteoporosis at primary health care level. WHO, Geneva
11. Panagiotakos DB, Pitsavos C, Stefanidis C (2006) Dietary patterns: a Mediterranean diet score and its relation to clinical and biological markers of cardiovascular disease risk. Nutr Metab Cardiovasc Dis 16:559–568
12. Weaver CM (2014) How sound is the science behind the dietary recommendations for dairy? Am J Clin Nutr 99:1217S–1222S
13. Feskanich D, Meyer HE, Fung TT, Bischoff-Ferrari HA, Willett W (2018) Milk and other dairy foods and risk of hip fracture in men and women. Osteoporos Int 29:385–396
14. Bian S, Hu J, Zhang K, Wang Y, Yu M, Ma J (2018) Dairy product consumption and risk of hip fracture: a systematic review and meta-analysis. BMC Public Health 18:165
15. Biver E, Durosier-Izart C, Merminod F, Chevalley T, van Rietbergen B, Ferrari SL, Rizzoli R (2018) Fermented dairy products consumption is associated with attenuated cortical bone loss independently of total calcium, protein, and energy intakes in healthy postmenopausal women. Osteoporos Int 29:1771–1782
16. Iguacel I, Miguel-Berges L, Gómez-Bruton A, Moreno LA, Julián C (2018) Veganism, vegetarianism, bone mineral density, and fracture risk: a systematic review and meta-analysis. Nutr Rev 77:1–18
17. WHO (2003) Diet, nutrition and the prevention of chronic diseases. WHO Technical Report Series No. 916. WHO, Geneva
18. Ross AC, Taylor CL, Yaktine AL, Del Valle HB (2011) The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine. 634 p
19. Dolan E, Sale C (2019) Protein and bone health across the lifespan. Proc Nutr Soc 78:45–55
20. Rizzoli R, Biver E, Bonjour J-P, Coxam V, Goltzman D, Kanis JA, Lappe J, Rejnmark L, Sahni S, Weaver C et al (2018) Benefits and safety of dietary protein for bone health. Osteoporos Int:1–16
21. Durosier-Izart C, Biver E, Merminod F, van Rietbergen B, Chevalley T, Herrmann FR, Ferrari SL, Rizzoli R (2017) Peripheral skeleton bone strength is positively correlated with total and dairy protein intakes in healthy postmenopausal women. Am J Clin Nutr 105:513–525
22. Houillier P, Froissart M, Maruani G, Blanchard A (2006) What serum calcium can tell us and what it can't. Nephrol Dial Transplant 21:29–32