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Seasonal variation of serum vitamin D and the effect of vitamin D supplementation in Irish community-dwelling older people

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Abstract

Background: Ireland is at 53°N, and its population risk of vitamin D deficiency is high. Previous Irish studies suggested a significant seasonality of serum 25-hydroxyvitamin D [25(OH)D] and a beneficial effect of supplementation in raising 25(OH)D levels. However, in Irish older people, little is known about the magnitude of the supplementation effect and whether supplementation affects 25(OH)D seasonality.

Design: cross-sectional observational.

Setting: outpatient clinic.

Subjects: five hundred and forty-six community-dwelling subjects (mean age 73.0, SD 7.4; 68.5% females) were assessed between September 2007 and May 2009.

Methods: for supplemented and non-supplemented: 'cosinor' analysis (Pulse_XP[®]) of monthly 25(OH)D. Period global solar radiation (GSR) and solar elevation angle (SEA) data were collected as proxy markers of ultraviolet-B radiation exposure. Multivariate linear regression was conducted to investigate the independent effect of GSR and SEA on 25(OH)D, controlling for confounders.

Results: supplemented group ($N = 183$): 89.1% were on cholecalciferol 800 IU/day. Mean 25(OH)D = 64.1 (95% confidence interval: 52.2–75.8) nmol/l, with no significant seasonality; regression: neither GSR nor SEA predicted 25(OH)D. Non-supplemented group ($N = 363$): mean 25(OH)D = 40.3 (35.5–45.0) nmol/l, with significant seasonality (55.5% variance remaining), peak in August, amplitude = 6.0 (3.1–8.8) nmol/l; regression: both GSR ($P = 0.002$) and the interaction GSR * SEA ($P = 0.018$) predicted 25(OH)D.

Conclusions: vitamin D supplementation was associated with a mean serum 25(OH)D increase of 23.8 nmol/l. Interestingly, supplementation seemed to blunt seasonality. In the supplemented group, 72.1% had individual 25(OH)D levels below the recommended 75 nmol/l. There is a case for universal supplementation in Irish older people, probably at a higher dose. Further research is needed to establish the optimum dose.

Keywords: vitamin D, seasonal variation, dietary supplements, aged, Ireland, elderly

Introduction

Serum 25-hydroxyvitamin D [25(OH)D] is a widely used and reliable marker of vitamin D status in humans [1], and its seasonal variation is a well-documented phenomenon [2]. The latter is a reflection of the importance of exposure to ultraviolet-B (UVB) radiation (wavelength 290–315 nm) as an initiator of the cutaneous synthesis of vitamin D [3]. The other main source of vitamin D in humans is dietary, but recent evidence suggests that in Caucasians, the typical daily intake of vitamin D from food contributes less than UVB exposure to average year-round 25(OH)D levels [4]. Therefore, appropriate UVB exposure is of great importance to achieve optimum vitamin D status; however, above 35°N latitude, the angle of the sun is too low from November to February, so little or no vitamin D can be produced (regardless of the amount of sunshine available) because most of the UVB radiation is absorbed by the atmosphere [5]. Other factors associated with increased risk of vitamin D deficiency are older age, female gender, darker skin pigmentation and poor dietary habits (i.e. reduced intake of vitamin D-rich foods) [6]. Obesity is also a well-recognised risk factor for vitamin D deficiency [7, 8]. Cross-sectional studies have found a positive association between exercise and vitamin D [9, 10], but debate remains as to whether this is a causal effect of vitamin D (i.e. those with a high vitamin D level are able to do more exercise) or is a consequence of sunshine exposure during outdoor physical activity [11].

Ireland is at 53°N latitude and its population risk of vitamin D deficiency is high. The intake of vitamin D supplements has been associated with decreases in total mortality rates [12], and in line with international recommendations [13], the Irish public health authorities encourage the uptake by older people of regular vitamin D (and calcium) supplementation [14]. Previous Irish studies suggested that exogenous vitamin D supplementation plays an important role in the prevention of vitamin D deficiency in older people [15, 16].

The seasonal variation of serum 25(OH)D in Irish older people is thought to be of significance. Previous small Irish studies reported winter as a significant negative predictor of serum 25(OH)D [17, 18]. Studies by Hill *et al.* [16, 19] in free-living postmenopausal women showed significantly higher values of serum 25(OH)D during summer than winter.

Despite the suggestions from the above small studies, the study of the seasonal variation of serum vitamin D in Irish older people has not yet been conducted using more accurate proxy markers of UVB exposure. Vitamin D synthesis in the skin does not map directly to season or month, but to the availability of sunlight of the appropriate wavelength, and the latter is not only dependent on the amount of sunshine but also on the solar elevation angle (SEA) [3], with an expected interactive effect. Furthermore, it is not known whether supplementation with vitamin D has an impact on the seasonality of serum 25(OH)D.

The aim of this study was to improve the understanding of the seasonality of serum 25(OH)D in Irish older people using as predictors better proxy markers of UVB exposure. We focused on the differences between supplemented and non-supplemented older people, as our aim was also to quantify the magnitude of the vitamin D supplementation effect in raising 25(OH)D levels.

Methods

Subjects and setting

Five hundred and forty-six subjects (mean age 73.0, SD 7.4; 68.5% females) were assessed at the Technology Research for Independent Living (TRIL) Clinic (<http://www.trilcentre.org/>) in Dublin between September 2007 and May 2009. The TRIL Clinic offers an outpatient clinical service to community-dwelling people over 60 years of age, in the form of a comprehensive geriatric assessment that incorporates the use of technologies and collection of biomarkers to measure risk factors for falls, cognitive decline and lack of social connectedness. The TRIL Clinic has a national scope and encourages referrals from all over Ireland, including self-referrals. TRIL Clinic participants must be community-dwelling, aged 60 and over, able to mobilise independently with or without mobility aid and able to provide informed consent. Local Research Ethics Committee approval was obtained (SJH/AMNCH Research Ethics Committee approval reference number 2007/06/13). All participants gave their informed consent prior to their inclusion in the study.

Less than 1% of the subjects were of ethnicity other than White Irish (Table 1), which makes the sample homogeneous regarding skin types. None had any known systemic conditions likely to affect 25(OH)D levels (e.g. severe generalised skin disease, malabsorption, severe liver disease, nephrotic syndrome, primary hyperparathyroidism, untreated hyperthyroidism or active granulomatous disorders) [5]. All subjects were ordinarily resident in Ireland (99.3% in the Republic of Ireland, 0.7% in Northern Ireland) and 79.7% had the home address within County Dublin. Travel histories (e.g. recent holidays at different latitudes) were not collected as part of the assessments. Sunlight exposure questionnaires were not used as there is evidence that they tend to provide imprecise estimates [20, 21].

The 546 subjects were seen over 21 consecutive months (September 2007–May 2009). For the breakdown of participants by month and vitamin D supplementation, see Supplementary data available in *Age and Ageing* online.

Measures

Serum vitamin D

Serum 25(OH)D (in nmol/l) was analysed at St James's Hospital Biochemistry Department using the DiaSorin

Table 1. Comparison of baseline characteristics between supplemented and non-supplemented subjects, by gender. SD, standard deviation; 25(OH)D, 25-hydroxyvitamin D; PTH, parathyroid hormone; ALP, alkaline phosphatase; eGFR, estimated glomerular filtration rate (Cockcroft–Gault formula); BMI, body mass index; MNA[®], Mini-Nutritional Assessment; TGUG, timed get up and go; IADL, independent activities of daily living; MMSE, Mini-Mental State Examination

	Females (N = 374)			Males (N = 172)		
	Not supplemented (N = 212)	Supplemented (N = 162)	P-value	Not supplemented (N = 151)	Supplemented (N = 21)	P-value
Socio-demographics						
Age (years) (SD)	72.5 (7.5)	73.5 (6.9)	0.199 ^a	73.2 (7.6)	73.2 (8.4)	0.934 ^b
White Irish ethnicity (%)	99.5	100	1.000 ^c	99.3	100.0	1.000 ^c
Manual social class (%)	39.0	36.4	0.618 ^d	42.6	42.9	0.979 ^d
Active smoker (%)	7.2	8.1	0.746 ^d	11.3	20.0	0.279 ^c
Self-referrals (%)	68.4	67.9	0.919 ^d	66.9	61.9	0.651 ^d
Calcium metabolism						
25(OH)D (nmol/l) (SD)	37.7 (18.1)	62.5 (23.9)	<0.001^a	42.5 (22.3)	61.1 (18.7)	<0.001^b
PTH (pg/ml) (SD)	48.2 (23.3)	42.0 (15.8)	0.004^a	49.0 (22.6)	45.4 (25.6)	0.308 ^b
Calcium (mmol/l) (SD)	2.4 (0.1)	2.3 (0.1)	0.318 ^a	2.3 (0.1)	2.3 (0.1)	0.250 ^b
Phosphate (mmol/l) (SD)	1.1 (0.2)	1.1 (0.2)	0.173 ^a	0.9 (0.2)	1.0 (0.1)	0.092 ^b
ALP (U/l) (SD)	84.7 (32.8)	69.3 (21.7)	<0.001^a	79.9 (36.9)	78.4 (43.0)	0.798 ^b
eGFR (ml/min) (SD)	73.2 (25.1)	68.2 (20.9)	0.045^a	75.1 (21.8)	71.0 (27.8)	0.480 ^b
Nutrition						
BMI (kg/m ²) (SD)	27.0 (4.7)	25.8 (4.5)	0.008^a	27.3 (4.0)	25.9 (4.2)	0.128 ^b
Abnormal MNA [®] (%)	7.2	9.4	0.433 ^d	8.7	5.0	1.000 ^c
Functional markers and history of falls and fractures						
Grip strength (kg) (SD)	20.0 (6.5)	18.5 (5.9)	0.027^a	32.4 (12.1)	27.8 (9.5)	0.090 ^b
TGUG (s) (SD)	10.3 (4.9)	10.3 (4.6)	0.920 ^a	9.7 (4.4)	12.2 (8.3)	0.640 ^b
Hours per week walking outdoors (SD)	3.7 (2.4)	3.6 (2.4)	0.783 ^b	3.9 (2.3)	3.8 (2.7)	0.907 ^b
Gait velocity (m/s) (SD)	1.0 (0.3)	1.0 (0.3)	0.875 ^a	1.1 (0.3)	1.1 (0.4)	0.877 ^b
Berg balance score (SD)	51.4 (6.4)	51.1 (7.6)	0.946 ^b	51.5 (6.1)	50.4 (8.3)	0.939 ^b
IADL score (SD)	25.5 (2.3)	25.2 (2.9)	0.281 ^b	25.3 (2.8)	24.8 (4.3)	0.820 ^b
≥2 falls in the last year (%)	16.7	23.0	0.127 ^d	17.2	14.3	1.000 ^c
≥1 fall-related fracture in the last 5 years (%)	15.0	23.3	0.043^d	8.8	9.5	1.000 ^c
Co-morbidities						
Charlson co-morbidity index (SD)	1.8 (1.9)	2.0 (2.0)	0.386 ^b	2.3 (2.2)	3.1 (2.8)	0.237 ^b
Cognition						
MMSE score (SD)	27.3 (2.7)	27.6 (2.6)	0.353 ^b	27.2 (2.5)	27.1 (2.4)	0.652 ^b
Subjective health						
Self-rated health (worst: 0; best: 10) (SD)	7.8 (1.5)	7.5 (1.6)	0.162 ^b	7.4 (1.7)	6.9 (2.8)	0.905 ^b

Significant *P*-values (< 0.05) are highlighted in bold.

^aIndependent samples *t*-test (two-sided).

^bMann–Whitney *U*-test (two-sided).

^cFisher's exact test (two-sided).

^dPearson's χ^2 test.

LIAISON[®] 25-OH Vitamin D TOTAL (<http://www.diasorin.com/en/productsandsystems/view/20>), a chemiluminescence immunoassay. Inter- and intra-assay coefficients of variation were <12%. Internal quality control was determined using kit controls of two different concentrations. The laboratory participates in the International Vitamin D External Quality Assessment Scheme (DEQAS, subgroup Liaison users) as a means of determining accuracy of results.

Vitamin D supplementation

It was ascertained from the medication histories taken by the study physicians. Subjects were regarded as supplemented if they reported regular intake of prescription

medicines and/or over-the-counter preparations (i.e. cod liver oil or multivitamin preparations) containing vitamin D.

Sunshine

Global solar radiation (GSR) data (MJ/m²) were obtained from the Monthly Weather Bulletins of the Irish Meteorological Service (<http://www.met.ie/climate/monthly-weather-bulletin.asp>, last accessed: 20 July 2010). Dublin Airport observatory was chosen among the other synoptic stations (<http://www.met.ie/about/weatherobservingstations/synopmap.asp>) as it was the closest to the majority of participants' addresses. 'Solar radiation' is defined as the energy from the sun in the form of ultra-violet, visible and infrared electromagnetic radiation, and

'GSR' is defined as the sum of the direct beam plus the diffuse component on a horizontal surface (http://www.met.ie/about/valentiaobservatory/solar_radiation.asp).

Solar elevation angle (in degrees)

Angle defined by an imaginary line between the observer and the sun, and the horizontal plane the observer is standing on. The higher the SEA, the more perpendicular the solar beam falls on the observer and the more likely UVB reaches the skin [22]. SEA data were obtained from the SunPosition® online calculator (<http://www.susdesign.com/sunposition/index.php>, last accessed: 20 July 2010), using the following settings: time basis: solar time; data to calculate: altitude; location: latitude 53.33°N (Dublin); frequency: monthly; resolution: once a day; start date: 1 September (i.e. data given for the first day of each month); time: 12:00; angle units: degrees.

Other measures and non-multivariable statistical analyses

See Supplementary data available in *Age and Ageing* online.

Assessment of seasonality

It was done by cosinor analysis, a technique that has been used in analogous cross-sectional epidemiological studies [23, 24]. We used the COSINE module of PULSE_XP (<http://mljohnson.pharm.virginia.edu/home.html>, last accessed: 21 July 2010), fitting a sine curve (of constrained 12-month periodicity) to the observed monthly data. Each curve was automatically characterised with the following parameters [and their 95% confidence intervals (CI)]: mean, amplitude (i.e. difference between peak and mean), acrophase (i.e. time at which the peak occurs, having defined 1 as September, 2 as October and so on), slope and percentage of remaining variance (0% = perfect fit). Graphic representations of the fitted sine waves were also obtained. Cosinor analyses were conducted for 25(OH)D (supplemented and non-supplemented), GSR and SEA (the latter was expected to have a tight fit).

Multivariable regression analyses

Separately for supplemented and non-supplemented, we tested whether GSR, SEA and the interaction GSR*SEA were significant predictors of 25(OH)D in the presence of the following confounders: gender, abnormal Mini-Nutritional Assessment (MNA®), age, body mass index (BMI), general mobility (timed get up and go, TGUG) and renal function (Cockcroft–Gault estimated glomerular filtration rate, eGFR). We used the SPSS general linear model (univariate) procedure, with 25(OH)D as a dependent variable, gender and abnormal MNA® as fixed factors and all the other predictors as covariates. To verify the assumptions, the Levene test of equality of error variances was requested. Assumptions of linearity and

normality of the residuals were also checked. A 0.05 level of significance was used throughout.

Results

Of the 546 participants, 363 (66.5%) were not on vitamin D supplements. Among the 183 supplemented, the most common type was cholecalciferol (vitamin D₃) at 800 IU/day (89.1%) or 2,800 IU/week (0.5%), followed by vitamin D-containing multivitamins (4.9%), cod liver oil (3.8%) and alfalcidol at 0.25 µg/day (1.6%).

Table 1 compares baseline characteristics between supplemented and non-supplemented subjects. The comparisons are grouped by gender to avoid confounding by potential gender differences in some of the comparing variables (e.g. physical performance measures). Females were more likely to be on vitamin D supplements than males (43.3 versus 12.2%; odds ratio = 5.5, 95% CI: 3.3–9.1).

Figure 1 shows the PULSE_XP-fitted sine curves for serum 25(OH)D (supplemented and non-supplemented

Figure 1. Graphical outputs (from PULSE_XP®) of the cosinor analyses of serum 25(OH)D (supplemented and non-supplemented), GSR and SEA during the study period.

Table 2. Parameter estimates for the multiple regression analyses in the supplemented ($N = 183$) and non-supplemented ($N = 363$) groups. 25(OH)D, 25-hydroxyvitamin D; MNA[®], Mini-Nutritional Assessment; BMI, body mass index; TGUG, timed get up and go; eGFR, estimated glomerular filtration rate (Cockcroft–Gault formula); GSR, global solar radiation; SEA, solar elevation angle. The standardised coefficients (β) were obtained with SPSS regression procedure

Dependent variable: serum 25(OH) D							
Parameter	<i>B</i>	β	Std. error	<i>t</i>	<i>P</i> -value	95% confidence interval	
						Lower bound	Upper bound
Supplemented group ($N = 183$)							
Intercept	95.38		31.95	2.99	0.003	32.28	158.48
Gender (male)	-1.31	0.02	5.62	-0.23	0.816	-12.42	9.80
Abnormal MNA [®] (no)	-11.42	0.13	7.61	-1.50	0.135	-26.45	3.61
GSR (MJ/m ²)	0.08	0.53	0.05	1.50	0.135	-0.02	0.17
SEA (in degrees)	0.09	0.06	0.36	0.25	0.801	-0.62	0.80
Age	-0.01	0.00	0.38	-0.03	0.974	-0.77	0.74
BMI (kg/m ²)	-1.11	-0.21	0.51	-2.17	0.031	-2.11	-0.10
TGUG (s)	-0.09	-0.02	0.43	-0.20	0.842	-0.93	0.76
eGFR (ml/min)	-0.04	-0.03	0.14	-0.28	0.783	-0.30	0.23
GSR * SEA	-0.00	-0.51	0.00	-1.17	0.245	-0.00	0.00
Non-supplemented group ($N = 363$)							
Intercept	89.82		17.62	5.10	<0.001	55.16	124.49
Gender (male)	5.25	-0.13	2.09	2.52	0.012	1.15	9.36
Abnormal MNA [®] (no)	2.90	-0.04	4.33	0.67	0.504	-5.62	11.41
GSR (MJ/m ²)	-0.09	-0.72	0.03	-3.12	0.002	-0.15	-0.03
SEA (in degrees)	0.16	0.12	0.20	0.83	0.408	-0.23	0.55
Age	-0.35	-0.13	0.19	-1.81	0.071	-0.73	0.03
BMI (kg/m ²)	-0.14	-0.03	0.28	-0.50	0.619	-0.69	0.41
TGUG (s)	-1.05	-0.25	0.26	-3.97	<0.001	-1.57	-0.53
eGFR (ml/min)	-0.16	-0.18	0.07	-2.41	0.017	-0.28	-0.03
GSR * SEA	0.00	0.67	0.00	2.37	0.018	0.00	0.00

Significant *P*-values (< 0.05) are highlighted in bold.

groups), GSR and SEA. Each of the sine curves is superimposed to the monthly observed data.

Cosinor analysis of serum 25(OH)D, supplemented group ($N = 183$). The fitted sine curve had the following parameters: period = 12 months; amplitude = 5.2 (95% CI: -2.1 to 12.2) nmol/l; acrophase = month 8.6 (i.e. April–May) (95% CI: 5.8–11.1); mean = 64.1 (52.2–75.8) nmol/l; slope = -0.2 (-1.2 to 0.7) radians; variance remaining = 100.0%.

Cosinor analysis of serum 25(OH)D, non-supplemented group ($N = 363$). Period = 12 months; amplitude = 6.0 (95% CI: 3.1–8.8) nmol/l; acrophase = month 12.0 (i.e. August) (95% CI: -0.9 to 1.0); mean = 40.3 (35.5–45.0) nmol/l; slope = -4.7 (-0.4 to 0.3) radians; variance remaining = 55.5%.

Cosinor analysis, GSR data. Period = 12 months; amplitude = 241.7 (95% CI: 220.3–263.2) MJ/m²; acrophase = month 10.0 (i.e. June) (95% CI: -2.1 to -1.8); mean = 307.6 (277.2–338.0) MJ/m²; slope = -1.4 (-3.9 to 1.1) radians; variance remaining = 3.6%.

Cosinor analysis, SEA data. Period = 12 months; amplitude = 23.2 (95% CI: 23.1–23.4)°; acrophase = month 10.7 (i.e. July) (95% CI: 10.6–10.7); mean = 37.0 (36.9–37.1)°; slope = 0 (0.0–0.0) radians; variance remaining = 0.0% (perfect fit as expected).

Multiple regression analysis, supplemented group ($N = 183$) (Table 2). Overall, the regression was not significant ($P =$

0.053, adjusted $R^2 = 0.048$), although BMI had a significant individual effect ($P = 0.031$). Neither GSR nor SEA was predictive of 25(OH)D. The Levene test was not significant ($P = 0.192$), meeting the homogeneity of variances assumption. Assumptions of linearity and normally distributed errors were met (see Supplementary data available in *Age and Ageing* online).

Multiple regression analysis, non-supplemented group ($N = 363$) (Table 2). The regression was significant ($P < 0.001$, adjusted $R^2 = 0.132$), with a favourable Levene test ($P = 0.223$). Assumptions of linearity and normally distributed errors were met (see Supplementary data available in *Age and Ageing* online). GSR ($P = 0.002$) and GSR * SEA ($P = 0.018$) were significant predictors, together with gender ($P = 0.012$), TGUG ($P < 0.001$) and eGFR ($P = 0.017$).

Discussion

In this sample of Irish community-dwelling older people, subjects taking vitamin D supplements had a higher mean serum 25(OH)D (64.1, 95% CI: 52.2–75.8 nmol/l) than those not taking supplements (40.3, 95% CI: 35.5–45.0 nmol/l). The effect is clear from the lack of overlap between 95% CIs. In other words, vitamin D supplementation (typically cholecalciferol 800 IU/day) was associated with a mean serum 25(OH)D increase of 23.8 nmol/l.

This strong effect of supplementation is consistent with observations from recent Irish studies [25, 26]. In supplemented women, higher 25(OH)D was seen together with lower parathyroid hormone and alkaline phosphatase (Table 1), as clinically expected [27].

In the supplemented group, 25(OH)D seasonality was not detected, which may be due to: (i) the relatively small size of this group (i.e. possible underpower); (ii) a hypothetical biological ‘blunting’ effect, whereby supplementation would increase serum 25(OH)D to an extent that would exceed the ‘background’ seasonal effect of UVB exposure; and/or (iii) the possibility that supplemented people have less exposure to UVB. Regarding (ii), it seems contradicted by a Spanish study that observed a significant seasonality of serum 25(OH)D in 53 obese adults who were supplemented after bariatric surgery [28]. However, in the Irish latitude, the hypothesis merits further exploration.

In relation to (iii), Table 1 shows no significant differences between supplemented and non-supplemented in parameters of physical mobility or activity. However, other comparisons suggest trends towards higher frailty levels in the supplemented subgroups, despite higher serum 25(OH)D levels (i.e. for BMI, eGFR and grip strength in females, where $P < 0.05$). Our interpretation is that in this sample, vitamin D supplementation could be a marker of greater frailty, perhaps in relation to the higher number of health-care episodes involving frailer people and the associated increased odds of being prescribed vitamin D. This would be supported by the observation that supplemented women had more history of fall-related fractures ($P = 0.043$).

We found a significant seasonality of 25(OH)D in the non-supplemented group. The 25(OH)D peak (August) occurred 2 months after the GSR peak (June) and 1 month after the SEA peak (1 July in our data, close to the summer solstice date). Previous research by van der Mei *et al.* [29] (Australia) estimated that the lag time between the estimated peak of maximum daily duration of vitamin D synthesis and the estimated peak in serum 25(OH)D was 26 days for southeast Queensland, 53 days for the Geelong region and 47 days for Tasmania.

As yet, there is no universal consensus on the level of serum 25(OH)D that reflects optimum vitamin D status; however, the International Osteoporosis Foundation recently recommended a target level of 75 nmol/l, from an evidence-based perspective [30]. In our sample, 95.3% of the non-supplemented and 72.1% of the supplemented subjects were below 75 nmol/l. In that light, we conclude that there is a case for universal supplementation of Irish older people with vitamin D, and perhaps at a dose higher than 800 IU/day of cholecalciferol. Limitations of our study include the relatively small sample sizes, the lack of information on compliance with supplementation and the possible lack of population representativity, due to non-random sampling. Further research in larger population-based samples and, ideally, in longitudinal

settings will help establish the optimum supplementation doses.

Key points

- The mean serum 25(OH)D level in Irish community-dwelling older people not taking vitamin D supplements was 40.3 nmol/l.
- Standard vitamin D supplementation (typically cholecalciferol 800 IU/day) was associated with an increase of 23.8 nmol/l in serum 25(OH)D.
- There was no evidence of 25(OH)D seasonality in the supplemented group.
- In the non-supplemented group, there was evidence of seasonality, with peak level (46.3 nmol/l) in August, ~2 months after the recorded peak in GSR.
- In the supplemented group, 72.1% had 25(OH)D levels below the recommended 75 nmol/l.
- There is a case for universal vitamin D supplementation of Irish older people.

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Supplementary data

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

Conflicts of interest

None declared.

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