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Original article

# Lower vitamin D status in obese compared with normal-weight women despite higher vitamin D intake in early pregnancy

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SUMMARY

*Background:* Obesity is associated with lower vitamin D concentrations than normal-weight. Pregnancy may affect vitamin D status, especially in obese subjects.
*Aims:* The purpose of this study was to compare vitamin D status and intake between obese and normal-weight women during pregnancy.
*Methods:* Twenty-five obese and 80 normal-weight women were recruited in the Western Sweden region (latitude 57°N). Blood samples and information on diet and sun exposure were collected in each trimester during pregnancy.
*Results:* During summer months, 12% of normal-weight and 50% of obese women in the first trimester had serum 25(OH)D concentrations <50 nmol/L ($P < 0.01$). Supplement use, body fat mass, season of blood sampling, and travelling to southern latitudes were the most important determinants of vitamin D status. Obese women had higher reported dietary vitamin D intake in early pregnancy compared with normal-weight women. Usage of supplements containing vitamin D was 61% in early pregnancy and declined thereafter. Nine percent of normal-weight and 33% of obese women ($P < 0.01$) reported a dietary vitamin D intake according to national recommendations in the beginning of pregnancy.
*Conclusions:* Half of the obese women had what could be considered as suboptimal vitamin D status in early pregnancy and lower vitamin D status compared with normal-weight women despite reporting a higher dietary vitamin D intake. A majority of the women did not reach intake of vitamin D according to dietary recommendations.


## 1. Introduction

Obesity is associated with lower 25-hydroxyvitamin D [25(OH)D] concentrations [1]. A proposed explanation for this is volumetric dilution [2]. The neonatal vitamin D concentrations reflect maternal ones, and a low vitamin D status in neonates of mothers with pre-pregnancy obesity has been shown [3]. Lower maternal vitamin D status has been associated with low birth weight [4], gestational diabetes [5], and pre-eclampsia [6]. An optimal vitamin D status during pregnancy could contribute to a reduction in pregnancy-related complications in obese women.

There are two sources of vitamin D: synthesis in the skin by ultraviolet B irradiation and dietary intake, including dietary supplements. In Sweden, low-fat (≤1.5%) milk, soured milk, some yoghurts and margarines are fortified. During winter months there is little or no synthesis of vitamin D in the skin at northern latitudes [7]. The national recommendation for vitamin D intake during pregnancy in Sweden is 10.0 μg/day [8]. Dietary intake and sun exposure habits may differ between countries that make region- and population-specific research of vitamin D important. A recent Swedish study showed mean vitamin D intakes below the Nordic recommendations [9]. In northern European studies, usage of vitamin D-containing supplements during pregnancy has been found to be 56–68%, and has shown to contribute substantially to vitamin D intake in supplement users [9,10].

In pregnancy, circulating 25(OH)D has been negatively associated with increasing body mass index (BMI), higher parity and

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darker skin-tone [11,12], and positively associated with supplement use, travels to sunny countries, sunny season [9], and total vitamin D intake [13].

Only a few studies have examined vitamin D intake and status in Swedish pregnant women [9,14] and none of these have compared normal-weight and obese women or presented longitudinal data during pregnancy. Longitudinal studies from countries on similar latitudes as Sweden showed that from approximately 30% [15] to as high as 96% [16] of pregnant women had circulating 25(OH)D levels below 50 nmol/L at some point of time during pregnancy. These studies did not include information on dietary intake of vitamin D, and data for obese women was not presented separately. Cross-sectional studies in countries on similar latitudes as Sweden have reported 25(OH)D levels <50 nmol/L in 28–65% of pregnant women [9,11].

Due to previously found differences in vitamin D status in pregnant women, and because pregnancy is a vulnerable period for both the woman and the growing fetus, the aim of this study was to analyse and compare vitamin D status and dietary intake of vitamin D during pregnancy in obese compared with normal-weight women living at a northern latitude.

## 2. Subjects and methods

### 2.1. Study design and population

Twenty-five obese and 80 normal-weight women were recruited between April 2009 and November 2012 in the Pregnancy Obesity Nutrition & Child Health study (PONCH). PONCH is an ongoing randomized controlled trial with the purpose to study the health of normal-weight and obese women during pregnancy and postpartum. Inclusion criteria were >20 years of age and BMI 18.5–24.9 or >30.0 kg/m$^2$. Exclusion criteria were non-European descent, diabetes, use of neuroleptic drugs, and vegan diet. Women were recruited through the maternity care, postings at public billboards, and advertisement on a website addressing pregnant women. All women were inhabitants in the Western Sweden region (latitude 57°N). Women were randomized to dietary intervention with focus on improvement of healthy eating habits or to a control group. The women had pre-planned visits in the study in the first (gestational week 8–12), second (gestational week 24–26) and third trimester (gestational week 35–37) of pregnancy. Women were included and randomized on age, self-reported BMI or BMI reported from the maternity care and parity. At the first visit four women had measured BMIs outside inclusion criteria. Two women included in the normal-weight group (18.0 and 25.0 kg/m$^2$), and two women included in the obese group (29.0 and 29.7 kg/m$^2$). In the current analysis, the intervention and control group are combined.

The study was approved by the Ethics Committee at the University of Gothenburg. Prior to entering the study, oral and written information was given to each participant, and written informed consent was obtained before entering the study.

### 2.2. Anthropometry and body composition

Body weight was measured in light-weighted indoor clothing on a digital scale to the nearest 0.1 kg. Height was measured at the first visit with a wall-mounted height scale to the nearest 0.5 cm. Body volume of the subject was measured with the BodPod® (Cosmed Inc., Rome, Italy) by air displacement plethysmography. Body volume in combination with body mass calculated body density [17]. The BodPod uses the principles of whole body densitometry to estimate fat mass (FM). Body composition was calculated with the BodPod® software using the equation of Siri [18]. Body weight and body composition measurements were carried out at all study visits.

### 2.3. Dietary intake

A self-administered dietary questionnaire mirroring the habitual diet during the last three months was used [19]. The dietary questionnaire is semi-quantitative of food frequency design that also considers portion sizes for hot meals, sandwiches and candies. The dietary questionnaire has been validated in men and non-pregnant women against a 4-day food record, 24-h energy expenditure and nitrogen excretion. From these comparisons, valid estimates of energy intake were obtained in normal-weight and obese subjects [19].

A food frequency questionnaire (FFQ) in which weekly intake of fish and shellfish during the last three months were asked for was answered by the participants at all study visits.

Women using vitamin D-containing supplements during the last six months before the start of pregnancy, or since the beginning of pregnancy, with no termination during that time, were considered supplement users in the first trimester. Women who stated use of vitamin D-containing supplements since the last study visit were considered supplement users at the second and third trimester.

### 2.4. Dietary intervention

The purpose of the dietary intervention was to improve dietary quality according to the Nordic Nutrition recommendations [8]. The intervention focused especially on increased fish, vegetable and fruit intake, as well as decreased intake of sucrose. Both normal-weight and obese women received the same dietary advices in the intervention apart from energy intake recommendations. Normal-weight women were recommended to increase energy intake with 350 kcal/day in the second trimester and with 500 kcal/day in the third trimester. The obese women were recommended a moderate energy restriction of 20% from daily estimated energy needs using the Harris-Benedict equation [20] on basal metabolic rate with the addition of a physical activity level of 1.4. The obese women were not given any specific advice on increased energy intake in the second or third trimester. The dietary intervention, including visits and eight telephone calls in between the physical visits, was performed by a dietician during pregnancy and postpartum.

### 2.5. Sun exposure

At the first study visit, the participants were asked for time spent outdoors during daytime, travelling abroad, and usage of sunbed for the previous six months. These questions were repeated at all visits during the study, covering the time since their last study visit. Since usage of sunbeds was uncommon among the participants, it was not used in statistical analysis. In order to analyse seasonal effects on vitamin D status, the calendar year was divided into two periods: October–March ("winter"), and April–September ("summer") or into four periods: January–March, April–June, July–September, and October–December.

### 2.6. Laboratory analyses

Venous blood samples were obtained after an overnight fast. Serum (S) samples were frozen and stored at −80 °C. S-25(OH)D was measured using a competitive two-step chemiluminescent immunoassay (CLIA), (LIAISON®, DiaSorin, Italy). The manufacturer reported CV 17%, 12%, and 9% at levels of 22 nmol/L, 60 nmol/L, and

145 nmol/L, respectively. The lower limit of detection was 10 nmol/L 25(OH)$D_2$ and 25(OH)$D_3$ were not separately measured. Samples were measured in a laboratory taking part in the Vitamin D External Quality Assessment Scheme.

### 2.7. Statistics

Continuous variables are presented as means and standard deviations (s.d). Non-parametric tests were chosen due to limited sample size and several variables being not normally distributed. Quantitative variables were compared with Mann–Whitney *U* Test,and comparisons between proportions were performed using chi-square test. Spearman Rank Order Correlation test was used to explore correlation between S-25(OH)D and variables known to effect vitamin D status. Variables being statistically significant in bivariate correlations in first trimester were used in multiple linear regression models in each trimester to assess factors associated with S-25(OH)D. Also, multiple linear regression analysis was used to compare S-25(OH)D between normal-weight and obese women controlling for supplement use, travelling to southern latitude and season of blood sampling. The repeated measures of dietary vitamin D and vitamin D-containing supplement for each participant were analysed using linear mixed models with control/intervention group, time and interaction terms as fixed factors. For vitamin D analyses, <25, >50, and >75 nmol/L were chosen according to proposed cut-offs [21,22]. A *P*-value <0.050 (two-tailed) was considered statistically significant. All statistical calculations were performed using IBM SPSS statistics 19.0 (IBM, New York, NY, USA).

## 3. Results

Study drop-outs are shown in Fig. 1. Obese women had lower gestational weight gain (GWG) compared with normal-weight women ($P = 0.029$). Normal-weight and obese women who dropped out had shorter education compared with study completers ($P < 0.001$). Obese women who dropped out had borderline higher fish intake ($P = 0.050$). There were no differences in age, parity, BMI, energy intake, dietary vitamin D intake, use of supplements or randomization group between women who dropped out and those who did not.

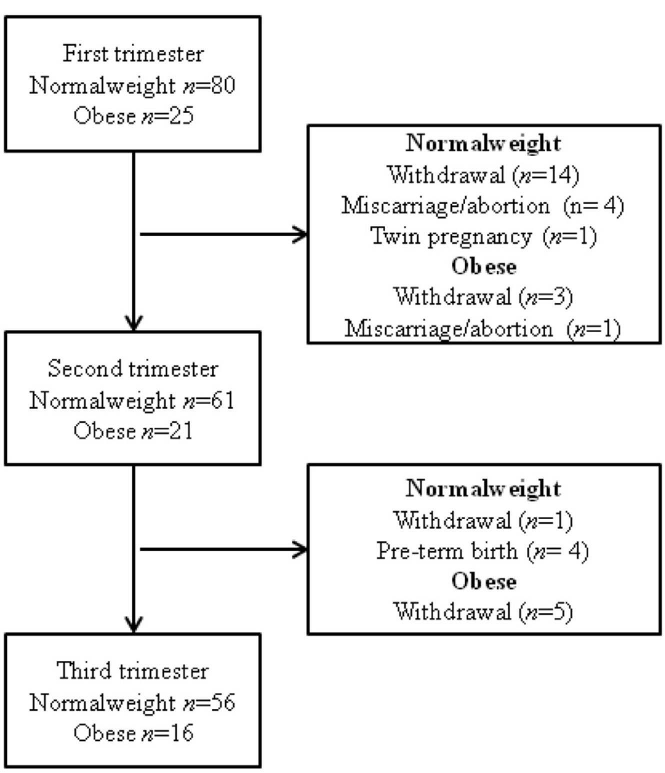


**Fig. 1.** Flow chart of the inclusion and follow-up during pregnancy.

### 3.1. Vitamin D status

Baseline characteristics, body composition and weight gain in the normal-weight and obese women are shown in Table 1. Compared with the normal-weight women, obese women had lower S-25(OH)D in the first trimester ($P < 0.001$), but not in the second ($P = 0.17$) and third trimester ($P = 0.78$) (Table 2). After controlling for season of blood sampling, supplement use, and travelling to a southern latitude, obese women had 11.4 nmol/L lower S-25(OH)D in the first trimester compared with normal-weight women ($P < 0.01$). When controlling for season for blood sampling, supplement use and travelling to a southern latitude in the second and third trimester, obese women had 8.2 and 5.7 nmol/L, respectively, lower S-25(OH)D than normal-weight women, but this did not reach statistical significance (Table 2).

In the first trimester, 12% of the normal-weight women had circulating 25(OH)D concentrations ≤50 nmol/L during summer in comparison to 50% of the obese women ($P < 0.01$) (Fig. 2). During winter season, in the first trimester, 40% of the normal-weight women had S-25(OH)D concentrations ≤50 nmol/L in comparison to 67% of the obese women ($P = 0.21$).

When dividing all women into groups having S-25(OH)D < 50 nmol/L or ≥50 nmol/L, women with concentrations >50 nmol/L were more likely to be supplement users ($P = 0.017$), and had a tendency to have a higher mean intake of low-fat (≤1.5%) milk, soured milk, and yoghurt ($P = 0.075$).

### 3.2. Vitamin D intake

Dietary intake is shown in Table 2. The obese women had a higher intake of vitamin D compared with the normal-weight women in the first trimester, and a larger proportion of the obese women had a vitamin D intake above the national recommendation (10.0 μg/day) compared with normal-weight women in the first trimester (Table 2). In the first trimester, nine percent of normal-weight and 33% of obese women had a dietary vitamin D intake above the national recommendation for pregnant women. During pregnancy, almost all women used fortified spreads with no

**Table 1**
Baseline characteristics for study participants.

| | Normal-weight $n = 78–80$ | Obese $n = 24–25$ |
|---|---|---|
| Age (y) | 31.4 ± 4.0 | 32.0 ± 3.2 |
| Parity (*n*) | 0.5 ± 0.6 | 1.0 ± 0.9 |
| Gestational week (w) | 11.9 ± 1.0 | 11.5 ± 1.5 |
| Height (m) | 1.69 ± 0.06 | 1.69 ± 0.07 |
| Weight (kg) | 62.9 ± 6.1 | 96.6 ± 12.5 |
| BMI (kg/$m^2$) | 22.0 ± 1.4 | 33.9 ± 3.3 |
| Fat mass (%) | 26.5 ± 5.3 | 44.8 ± 4.4 |
| Fat mass (kg) | 16.7 ± 4.0 | 43.3 ± 9.0 |
| Gestational weight gain (kg) | 11.4 ± 2.5 | 9.0 ± 4.6 |
| Fat mass gain (kg) | 5.8 ± 2.7 | 4.2 ± 4.2 |
| Education, *n* (%) | | |
| Upper secondary school | 14 (17.5) | 9 (36.0) |
| <3 years at university level | 8 (10.0) | 4 (16.0) |
| ≥3 years at university level | 58 (72.6) | 12 (48.0) |

Values are means ± s.d or *n* (%).

**Table 2**
Dietary intake, sun exposure and vitamin D status during pregnancy.

| | 1st Trimester | | | 2nd Trimester | | | 3rd Trimester | | |
|---|---|---|---|---|---|---|---|---|---|
| | Normal weight $n = 76–80$[a] | Obese $n = 22–25$[a] | *P* | Normal weight $n = 54–56$[a] | Obese $n = 16–20$[a] | *P* | Normal weight $n = 51–54$[a] | Obese $n = 15–16$[a] | *P* |
| Energy intake (kcal/day) | 2252 ± 617 | 2529 ± 817 | 0.14 | 2316 ± 571 | 2448 ± 636 | 0.31 | 2354 ± 597 | 2337 ± 518 | 0.93 |
| Dietary vitamin D intake (µg/day) | 7.2 ± 2.5 | 8.8 ± 3.3 | **0.024** | 7.9 ± 2.7 | 8.2 ± 2.7 | 0.69 | 7.9 ± 2.3 | 8.1 ± 2.3 | 0.72 |
| Dietary vitamin D intake (µg/MJ) | 0.78 ± 0.24 | 0.84 ± 0.21 | 0.25 | 0.82 ± 0.23 | 0.83 ± 0.29 | 0.92 | 0.83 ± 0.25 | 0.85 ± 0.24 | 0.54 |
| Dietary vitamin D intake ≥ 10 µg/day, *n* (%) | 7 (9.2) | 8 (33.3) | **<0.01** | 13 (23.6) | 5 (29.4) | 0.75 | 10 (19.2) | 3 (20.0) | 1.00 |
| Supplement use, *n* (%)[b] | 49 (62.0) | 15 (60.0) | 1.00 | 25 (44.6) | 10 (47.6) | 1.00 | 30 (55.6) | 7 (46.7) | 0.57 |
| Dietary calcium intake (mg/day) | 1148 ± 483 | 1203 ± 655 | 0.76 | 1187 ± 402 | 1097 ± 331 | 0.57 | 1248 ± 416 | 1174 ± 427 | 0.53 |
| Fish- and shellfish intake (meals/w) | 2.5 ± 1.4 | 2.0 ± 1.1 | 0.18 | 2.9 ± 1.6 | 2.7 ± 1.5 | 0.71 | 2.8 ± 1.4 | 2.2 ± 1.6 | 0.074 |
| Total intake milk, soured milk and yoghurt (dl/day) | 2.5 ± 1.6 | 2.3 ± 1.9 | 0.62 | 2.7 ± 1.6 | 2.0 ± 1.1 | 0.080 | 2.7 ± 1.6 | 2.5 ± 1.2 | 0.65 |
| Intake milk, soured milk and yoghurt (dl/day) (fat content ≤1.5%) | 1.4 ± 1.7 | 1.3 ± 1.4 | 0.99 | 1.6 ± 1.8 | 1.2 ± 0.84 | 0.75 | 1.5 ± 1.5 | 1.7 ± 1.7 | 0.92 |
| Intake milk, soured milk and yoghurt (dl/day) (fat content >1.5%) | 1.1 ± 1.2 | 1.0 ± 1.7 | 0.18 | 1.1 ± 1.1 | 0.81 ± 1.2 | 0.31 | 1.2 ± 1.6 | 0.79 ± 0.71 | 0.74 |
| Use of fortified spread, *n* (%) | 64 (84.2) | 22 (91.7) | 0.51 | 49 (89.1) | 16 (88.9) | 1.00 | 44 (84.6) | 16 (100.0) | 0.18 |
| Use of fortified fats in cooking, *n* (%) | 12 (15.8) | 8 (33.3) | 0.080 | 7 (12.7) | 8 (47.1) | **<0.01** | 6 (11.5) | 8 (53.3) | **<0.01** |
| *Fish- and shellfish intake, (meals/w)* | | | | | | | | | |
| 0–1, *n* (%) | 19 (25.0) | 8 (36.4) | 0.31 | 13 (24.1) | 6 (40.0) | 0.33 | 7 (13.7) | 6 (40.0) | 0.070 |
| 2–3, *n* (%) | 40 (52.6) | 12 (54.5) | | 25 (46.3) | 4 (26.7) | | 30 (58.8) | 7 (46.7) | |
| >3, *n* (%) | 17 (22.4) | 2 (9.1) | | 16 (29.6) | 5 (33.3) | | 14 (27.5) | 2 (13.3) | |
| S-25(OH)D (nmol/l) | 64.2 ± 18.3 | 49.7 ± 11.5 | **<0.001** | 58.2 ± 18.3 | 49.7 ± 18.9 | 0.17 | 51.7 ± 18.3 | 47.7 ± 18.3 | 0.78 |
| Time spent outdoors (min/day) | 112 ± 76.7 | 145 ± 107 | 0.15 | 104 ± 68.6 | 99.1 ± 82.1 | 0.37 | 68.2 ± 47.5 | 88.8 ± 64.7 | 0.26 |
| Travel to southern latitude[c] | 17 (21.5) | 3 (12.0) | 0.39 | 3 (5.4) | 3 (15.0) | 0.18 | 2 (3.7) | 0 (0.0) | 1.00 |

Values are means ± s.d or *n* (%).
Data in bold indicate significance.
[a] The range of *n* is due to missing data (predominantly dietary questionnaires and FFQs).
[b] Vitamin D containing supplements.
[c] Travelling to a country below latitude 35°N within six months prior to blood sampling.

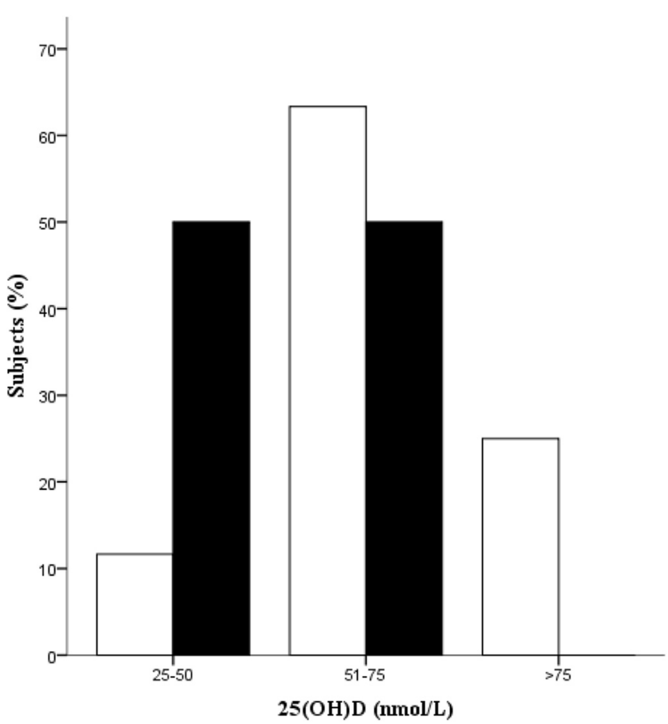


**Fig. 2.** Distribution of vitamin D status in the first trimester (April–September) in 60 normal-weight (*open bar*) and 16 obese (*filled bar*) women ($P < 0.01$).

differences between normal-weight and obese women. Obese women tended to use more fortified fats for cooking compared to normal-weight women during pregnancy.

Furthermore, there were no differences in intake of milk, soured milk and yoghurt between normal-weight and obese women (Table 2). In the linear mixed model analysis, no effects of the dietary intervention were found on dietary vitamin D intake ($P = 0.060$) or supplement use ($P = 0.70$).

### 3.3. Supplement use

In the first trimester, 61% of the women used vitamin D containing supplements with no differences between normal-weight and obese women (Table 2). Intake of vitamin D containing supplements was highest in the first trimester, and decreased to the second and third trimester with no differences between obese and normal-weight women (Table 2). The most common supplement used, was multivitamin- and mineral products. When separating supplement users and non-users in the first trimester, supplement users had higher total intake of milk and yoghurt ($P = 0.023$), and 9 nmol/L higher mean S-25(OH)D compared with non-users ($P < 0.01$).

### 3.4. Sun exposure

There were no differences between normal-weight and obese women in time spent outdoors or travelling to southern latitude at any time during pregnancy. There were few individuals travelling to southern latitude in the second and third trimester (Table 2).

### 3.5. Factors associated with circulating 25(OH)D

In bivariate correlations, season for blood sampling and supplement have statistically significant associations with S-25(OH)D in all trimesters. FM% was negatively associated with S-25(OH)D in all trimesters but reached statistical significance only in the first trimester. Travelling to a southern latitude was positively associated with S-25(OH)D in all trimesters, being statistically significant only in the first trimester. No statistical significant correlations were found between S-25(OH)D and dietary vitamin D intake, fish intake, age, parity, time spent outdoors, or intake of fortified foods.

In Table 3 the results from multiple regression analysis are shown. In the first trimester, FM% alone explained 11.2% of the variance in S-25(OH)D ($P < 0.01$) (Fig. 3).

## 4. Discussion

Obese compared with normal weight women are at risk for several complications during pregnancy due to the obesity [5,6]. Some of these complications have been suggested to be associated with low vitamin D status [4–6]. Few studies have compared normal weight and obese pregnant women in these respects. Thus, it is not known whether vitamin D status differ or not between normal weight and obese pregnant women. If so, women with low vitamin D status should be focused on during pregnancy.

### 4.1. Vitamin D status

We found lower mean S-25(OH)D concentration in pregnant obese compared with normal-weight women in the first trimester, but not in the second and third trimester. To our knowledge, this is the first report of vitamin D status in obese pregnant women in Sweden. The negative association between circulating 25(OH)D in obesity has been shown in earlier studies in pregnant [3,11], and Swedish non-pregnant women of childbearing age [23]. The relatively high drop-out rate and subsequent loss of power might explain why we did not find a difference in S-25(OH)D in the second and third trimester. The normal physiological changes during pregnancy such as heamo-dilution and weight changes could affect vitamin D status across the pregnancy. In general, obese women gain less weight during pregnancy compared to normal-weight [24]. Volumetric dilution has been proposed to explain the lower circulating 25(OH)D levels in obese individuals [2]. However, one might consider that the more often larger GWG in normal-weight women compared with obese women could attenuate the difference in 25(OH)D during pregnancy. Also, haemo-dilution during the pregnancy *per se* could contribute to the lower circulation 25(OH)D levels in both normal-weight and obese women. The effect of body size and pregnancy on volumetric dilution needs to be further explored.

Compared with a study including predominantly normal-weight Swedish women in late pregnancy who found a mean S-25(OH)D of 47.7 nmol/L [9], the mean 25(OH)D concentration was higher in the normal-weight women in the present study. In accordance with our study, although including women with different ethnicity, Sääf et al. found a mean S-25(OH)D of 66 nmol/L in early pregnancy [14]. Differences in circulating 25(OH)D between studies may depend on season of blood sampling, dietary intake, supplement use, differences in other lifestyle factors affecting vitamin D status or method used for measuring 25(OH)D.

There is an ongoing debate on cut-off levels for circulating 25(OH)D for optimal vitamin D status. Levels >75 nmol/L has been proposed as optimal levels for health in the non-pregnant state [21]. The Institute of Medicine (IOM) found no support for this cut-off value in their 2010 report, and suggested >50 nmol/L as sufficient [25]. In accordance with the results shown by Bodnar et al. [3], a larger proportion of the obese compared with normal-weight women in our study had S-25(OH)D concentrations <50 nmol/L. Only few women had circulating 25(OH)$D < 25$ nmol/L, suggesting that vitamin D deficiency is uncommon in healthy fair-skinned normal-weight and obese pregnant women in Sweden. If there is a need for specific cut-offs for obese individuals or during pregnancy is largely unknown.

Both 1,25-dihydroxyvitamin D and vitamin D-binding protein concentrations are increased during pregnancy demonstrating altered vitamin D metabolism during pregnancy [26]. However, studies on the effects of pregnancy on circulating 25(OH)D have shown conflicting results [15,16].

### 4.2. Vitamin D intake

Nine percent of the normal-weight women and 33% of the obese women had a dietary vitamin D intake above the national recommendation in the first trimester. Vitamin D intake below recommendations has been shown in other European studies of pregnant women [9,27]. We did not include vitamin D intake from supplements due to the lack of reliable self-reported data. However, if vitamin D containing supplements would be added to the dietary vitamin D intake, an increased proportion of the women in our study would probably have had an intake above the vitamin D intake recommendations. In a study with a similar population as in the present study, a mean intake of 5.8 μg/day of vitamin D from supplements in supplements users was found, and 39% of the women had a total vitamin D intake above the recommendations [8]. This suggests that, if supplements had been included in our results, still a considerable proportion of the women would have had intakes below recommendations.

In early pregnancy, mean dietary vitamin D intake in our study was 7.2 and 8.9 μg/day in normal-weight and obese women, respectively. Other reported lower vitamin D intake in pregnant

**Table 3**
Results from multiple linear regression analyses of selected factors that influence on serum 25(OH)D.

| | 1st trimester ($n = 100$) | | | $R^2$ | 2nd trimester ($n = 70$) | | | $R^2$ | 3rd trimester ($n = 64$) | | | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B[a] | Std. err | *P* | | B | Std. err | *P* | | B | Std. err | *P* | |
| Fat mass (%) | −0.5 | 0.17 | <0.01 | 31.1 | −0.5 | 0.24 | 0.032 | 23.3 | −0.5 | 0.27 | 0.097 | 21.1 |
| Season[b] | 6.2 | 1.53 | <0.001 | | 4.8 | 1.81 | <0.01 | | 6.8 | 2.02 | <0.01 | |
| Travel to southern latitude[c] | 10.6 | 3.90 | <0.01 | | 14.3 | 7.40 | 0.058 | | 14.4 | 12.0 | 0.235 | |
| Supplement use[d] | 8.7 | 3.15 | <0.01 | | 9.1 | 4.24 | 0.036 | | 9.2 | 4.16 | 0.031 | |

[a] B coefficients.
[b] Jan–March = 1, Oct–Dec = 2, April–June = 3, July–Sep = 4.
[c] Travelling to a country below latitude 35°N within six months prior to blood sampling (0 = no, 1 = yes).
[d] Supplements containing vitamin D (0 = no, 1 = yes).

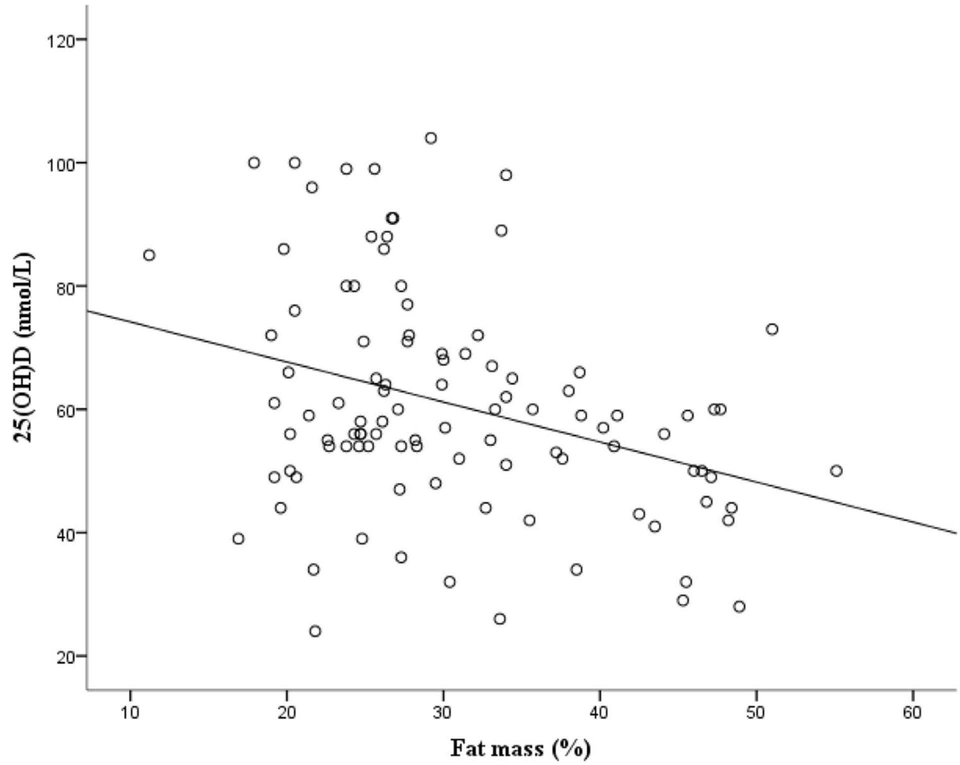


**Fig. 3.** Linear regression between 25(OH)D and fat mass (%) in the first trimester ($r$ [2] = 0.112, $P < 0.01$).

women [9]. This might be explained by a higher self-reported fish intake in our study, although Brembeck et al. [9] measured fatty fish intake only, but still higher compared to other woman of childbearing age in Sweden [28]. We found that the obese women reported a higher mean intake of dietary vitamin D compared with normal-weight women in the first trimester. This is in accordance with Watson et al. that found higher vitamin D intake with increasing BMI in pregnant women in New Zealand [29]. In contrast, other studies have shown lower reported vitamin D intake in obese compared to non-obese women [30]. Although no intervention effect on reported dietary vitamin D intake was found, the self-reported dietary intakes in the second and third trimester should be interpreted with caution due to the intervention design.

In Sweden, margarine, low-fat (≤1.5%) milk, soured milk, and some yoghurts are fortified with vitamin D. We found similar patterns in the reported intake of food fortified with vitamin D in normal-weight as in obese women. According to these results, the fortification in foods already fortified has an effect on dietary intake of vitamin D in both normal-weight and obese women.

### 4.3. Supplement use

Sixty-one percent of the women in the present study used vitamin D-containing supplements in early pregnancy, and supplement use decreased by the second and third trimester. We found no difference in supplement use between obese and normal-weight women. Other Scandinavian studies have found vitamin D supplement usage to be approximately 40% in late pregnancy [9]. There is no general advice on the use of supplements during pregnancy in Sweden but a general use of multivitamins/minerals seems to be widespread according to our and other studies [9]. Differences between studies might depend on national advice on supplement use during pregnancy, the ability to correctly report intake, difference in assessment methods, classification of supplements and different populations included.

### 4.4. Factors associated with vitamin D status

In accordance with other studies [9,11], factors associated with vitamin D status during pregnancy were FM%, season of blood sampling, supplement use, and travelling to a country at southern latitude. We found no association between dietary vitamin D intake and S-25(OH)D. Our sample size may be too small to detect such a relationship. Even so, the use of vitamin D containing supplements were positively correlated with circulating 25(OH)D implying that dietary intake has an effect on circulating 25(OH)D.

### 4.5. Limitations

The difficulties in recruiting obese women caused a considerable smaller group of obese women compared with normal-weight women. The drop-out rate was relatively high and the women in our study had a high educational level and might for that reason be more health conscious; therefore, the generalization of the results to the whole population of pregnant women may be limited. The question on supplement use in the present study did not produce valid information on brand and frequency leaving us unable to report total vitamin D intake. All women were fair-skinned and conclusions on women with other skin tones living in Sweden should be done with caution.

The clinical implications of the results from the present study are to be observant of pregnant women with an unbalanced diet including few vitamin D containing foods or if these foods are consumed on a irregularly basis. The results are not sufficient for a recommendation of screening for low vitamin D status. However, it could be argued that women, independent of body size with limited intake of vitamin D containing foods could be assessed for vitamin D status.

In conclusion, pregnant obese women had lower circulating 25(OH)D in the first trimester compared with pregnant normal-weight women despite reporting higher dietary vitamin D intake and a similar usage of vitamin D-containing supplements. Few women had a dietary intake of vitamin D above the recommendations during pregnancy, but obese women were more likely to reach the recommendation for vitamin D. Since vitamin D is found only in a limited amount of foods, it is important to promote intake of these foods to both normal-weight and obese pregnant women. Furthermore, although tentative, circulating 25(OH)D did not in the present group of normal-weight and obese women differ during second and third trimester of pregnancy, suggesting no major effect of obesity in mid and late pregnancy on circulating 25(OH)D. These findings should be further studied in larger groups, and in women with different skin-tones.

## Statement of authorship

The authors of this manuscript have contributed with following: conception and design of the study (TK, AHu, NJ, AH), analysis of data (TK), interpretation of data (TK, LA, AHu, MB, NJ, AO, LH, AH, IL), drafting the article (TK, IL) and revising it critically, (TK, AO, LH, IL). All authors have approved the final manuscript.

## Conflict of interest

The Authors declare no conflicts of interest.

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