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Assessing Vitamin D's Impact on Pregnancy Success: A Predictive

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Abstract

Background: Infertility, defined as the inability to conceive after at least 12 months of unprotected intercourse, affects up to 15.5% of couples of childbearing age. Assisted Reproductive Technology (ART) offers hope for successful pregnancy, though clinical pregnancy rates remain around 40%, with delivery success rates at 20%-30%. Despite numerous influencing factors, age, Antral Follicle Count (AFC), and Anti-Mullerian Hormone (AMH) serve as the current predictors of ART outcomes. However, these indicators lack comprehensive accuracy as they evaluate only specific stages of ART. Emerging research suggests a significant role for Vitamin D in reproductive physiology, yet its impact on the clinical pregnancy rates of *in-vitro* fertilization/intracytoplasmic sperm injection- embryo transfer (IVF/ICSI-ET) remains underexplored.

Purpose: This study analyzes various risk factors affecting clinical pregnancy rates in ART, emphasizing the role of Vitamin D levels in infertile women undergoing IVF/ICSI. We aim to correlate Vitamin D levels with ART-related factors and establish a predictive model for clinical pregnancy outcomes to guide personalized treatment plans and enhance ART success rates.

Keywords: Infertility, ART, Vitamin D, Factors affecting pregnancy, Logistic regression analysis

Introduction

Infertility impacts about 15% of couples globally, with treatments such as *in vitro* fertilization (IVF) and intracytoplasmic sperm injection (ICSI) offering hope yet yielding variable success rates. Although ART outcomes are influenced by factors like ovarian reserve, measured through antral follicle count (AFC) and anti-Müllerian hormone (AMH) levels, recent studies suggest a significant role of vitamin D in reproductive health [1,2]. Vitamin D receptors are widely expressed in reproductive tissues, and deficiency in vitamin D is common among women of childbearing age, raising questions about its impact on fertility and ART outcomes [3,4]. Research shows conflicting results on whether vitamin D levels correlate with improved ART success, indicating a need for further investigation [5,6].

This study aims to assess the relationship between serum vitamin D levels and clinical pregnancy rates in women undergoing IVF/ICSI. By exploring the potential of vitamin D levels alongside established predictors like AMH and AFC, we seek to enhance predictive models for ART outcomes, facilitating more personalized treatment approaches.

Methods

Study design and participants

This was a retrospective cohort study conducted at the Guangxi Medical University First Affiliated Hospital Reproductive Center. We enrolled 188 infertile patients who underwent routine IVF and ICSI treatments from June 2020 to July 2021. Patients were categorized into two groups based on clinical pregnancy outcomes: those who achieved successful pregnancy and those who did not.

Inclusion and exclusion criteria

Inclusion criteria included:

- Patients who underwent fresh embryo transfers.
- Complete follow-up records.

- No history of genetic diseases in either partner.
- No uterine abnormalities or concurrent adenomyosis in female patients.
- All participants were part of a controlled ovulation induction program.
- None had taken or injected vitamin D-related preparations within the previous 6 months.

Exclusion criteria included:

- Cancellation of the embryo transfer for any reason.
- Recipients of frozen embryo transfer.
- Patients with incomplete follow-up.
- Presence of systemic diseases such as diabetes, kidney disease, hypertension, or immune system disorders.

Data collection

Comprehensive data were collected, including:

- Baseline demographic and clinical characteristics (age, BMI, duration of infertility, type of infertility).
- Biochemical markers (AMH, AFC, and basal hormone levels including FSH, LH, E2, P, PRL, T, DHEA).
- Treatment details (COH protocol, total Gn dosage, duration of Gn administration), outcomes (endometrial thickness on the day of hCG administration, E2 levels on hCG day, number of oocytes retrieved, number of embryos obtained, clinical pregnancy outcome).

Laboratory methods

Vitamin D levels were measured using a chemiluminescence immunoassay (CLIA). All hormonal measurements were performed in the hospital's central laboratory under standardized conditions.

Statistical analysis

Data were analyzed using SPSS software version 20.0. Continuous variables were expressed as mean ± standard deviation or median where appropriate, and categorical variables as percentages. The differences between groups were assessed using Student's t-test for normally distributed data and the Mann-Whitney U test for non-normally distributed data. Chi-square or Fisher's exact test was used for categorical data. Logistic regression analysis was employed to identify independent predictors of clinical pregnancy. A p-value of less than 0.05 was considered statistically significant.

Results

Participant characteristics

Our study included 188 infertile patients undergoing IVF/ICSI treatment. The participants were divided into two groups based on clinical pregnancy outcomes: 71 (37.8%) achieved clinical pregnancy (successful pregnancy group) and 117 did not (unsuccessful pregnancy group).

Clinical and demographic data

The successful pregnancy group had significantly lower mean age (29.89 ± 4.03 years) compared to the unsuccessful group (32.42 ± 5.11 years; P=0.026). Differences in body mass index (BMI) were not statistically significant between the groups (**Table 1**).

Hormonal and biochemical markers

Significant differences were observed in serum vitamin D levels, with the successful pregnancy group showing higher levels (29.77 ± 13.3 μg/L) than the unsuccessful pregnancy group (24.97 ± 11.16 μg/L; P=0.03). Additionally, AMH and AFC were higher in the successful group compared to those who did not achieve pregnancy (AMH: 3.68 ng/mL vs. 2.99 ng/mL, P=0.04; AFC: 17.25 ± 5.98 vs. 13.25 ± 6.62, P=0.009) (**Table 1**).

Table 1. Demographic and clinical characteristics of clinical pregnancies conceived through ART.

Variable	Pregnancy group (71)	Non-pregnancy group (117)	P
Age, y	29.89 ± 4.03	32.42 ± 5.11	0.026*
BMI, kg/m^2	24.18 ± 2.98	24.37 ± 3.39	0.131
Infertility duration, y	4.53 ± 2.15	5.32 ± 2.31	0.011*
Infertility type			
Primary	45 (61.4%)	76 (65.0%)	0.236
secondary	26 (36.6%)	41 (35.0%)	0.421
AFC	17.25 ± 5.98	13.25 ± 6.62	0.009*

Vitamin D levels, μg	29.77 ± 13.3	24.97 ± 11.16	0.03*
AMH, ng/mL	3.68 ± 2.58	2.99 ± 1.41	0.04*
Basic sex hormone levels			
bFSH (m IU/ml)	6.92 ± 1.32	7.63 ± 1.01	0.032*
bLH (m IU/ml)	6.12 ± 2.16	5.98 ± 3.24	0.661
E_2 (pg/m L)	33.58 ± 14.42	34.89 ± 18.23	0.534
P (ng/ml)	0.86 ± 0.09	0.88 ± 0.08	0.732
PRL (ng/ml)	14.62 ± 8.77	14.92 ± 9.75	0.552
T (ng/dl)	0.36 ± 0.13	0.41 ± 0.15	0.085
DHEA	10.41 ± 6.32	9.36 ± 1.25	0.019*
COH type			
GnRH long regimen	42 (59.2%)	79(67.5%)	0.028*
GnRH antagonist regimen	29 (40.8%)	32(27.4%)	0.012*
Total amount of Gn	1728.88 ± 788.45	1833.67 ± 613.50	0.034*
Gn days	10.85 ± 3.21	10.77± 4.56	0.225
Fertilization mode (IVF/ICSI/Half–ICSI)			0.081
IVF	46 (64.8%)	82 (70.1%)	0.0635
ICSI	19 (26.8%)	31 (26.5%)	0.236
Half-ICSI	6 (8.5%)	4 (3.4%)	0.136
Number of pregnancies	1.12 ± 0.13	2.04 ± 0.35	0.019*
Endometrial Thickness on the Day of HCG	12.63 ± 2.09	10.52 ± 2.54	0.035*
HCG day E_2	2053.21 ± 186.14	1967.52 ± 204.14	0.474
Number of eggs obtained	15.52 ± 4.68	13.44 ± 5.99	0.023*
Number of embryos obtained	5.77 ± 0.46	4.64 ± 0.51	0.062

Table 2. Multifactorial logistic regression analysis related to pregnancy.

Variable	**β[a]**	**SE[b]**	**OR**	**OR (95% CI)**	**P**
Age, y	0.0921	0.1102	1.08	0.87–1.34	0.016*
AFC	1.0652	0.1136	2.51	2.00–4.93	0.033*
Vitamin D levels, μg	0.3758	0.1697	1.46	1.04–2.03	0.027*
AMH, ng/mL	0.1697	0.1224	2.03	1.63–3.21	0.037*
Basic sex hormone levels					
bFSH (m IU/ml)	0.9211	0.1254	1.04	1.35-3.67	0.358
DHEA	1.1021	0.2514	1.69	1.24-2.31	0.085
COH regimen					
GnRH long regimen	1.3684	0.3511	2.03	0.36–1.05	0.506

GnRH antagonist regimen	0.8564	0.3222	2.98	1.60–5.65	0.141
Total amount of Gn	0.3296	0.3621	1.26	1.02–1.55	0.030*
Number of pregnancies	1.1141	0.2536	1.85	0.98-1.85	0.194
Endometrial Thickness on the Day of HCG	1.6201	0.1024	0.68	1.28–2.04	0.019*
Number of eggs obtained	1.5634	0.1121	0.97	0.48–1.62	0.035*
Notes: OR: Odd Ratio; CI: Confidence Interval; *P<0.05; [a]β: Estimation parameters of regression models; [b]SE: Standard error of the regression models					

Table 3. Regression model of factors associated with infertility.

Variable	β[a]	SE[b]	OR	OR (95% CI)	P
Age, y	0.0733	0.1311	1.23	0.95–2.14	0.011*
AFC	0.2962	0.1421	2.14	1.35–3.26	0.037*
Vitamin D levels, μg	0.4214	0.2684	2.63	0.65–1.92	0.027*
AMH, ng/mL	1.3624	0.1651	3.97	0.79–2.10	0.3758
bFSH (m IU/ml)	0.1697	0.3321	4.25	1.60–5.65	0.4428
DHEA	2.3541	0.1241	0.58	0.95–3.65	0.321
GnRH long regimen	0.1774	0.3688	1.93	2.35–6.34	0.506
GnRH antagonist regimen	1.1000	0.1532	3.00	1.35–3.94	0.958
Total amount of Gn	0.2287	0.3263	2.68	0.95–2.57	0.032*
Number of pregnancies	0.8792	0.2547	3.82	0.84-2.15	0.381
Endometrial Thickness on the Day of HCG	0.2698	0.1698	1.98	2.04–4.32	0.020*
Number of eggs obtained	0.3241	0.1698	1.22	0.66-2.11	0.042*

Table 4. Comparison of basic information and pregnancy outcome in different vitamin D groups.

Variable	Vitamin D non-deficient group (116)	Vitamin D deficiency group (72)	P
Age, y	28.73 ± 3.054	28.58 ± 3.670	0.472
BMI	21.56 ± 1.84	21.56 ± 1.60	0.131
Infertility duration, y	3.05 ± 2.29	3.67 ± 2.27	0.451
Infertility type			0.593
Primary	45 (38.8%)	30 (41.7%)	
Secondary	71 (61.2%)	42 (58.3%)	
AMH, ng/mL	3.78 ± 2.58	3.62 ± 2.56	0.178
AFC	16.35 ± 3.52	15.71 ± 3.54	0.094
Basic sex hormone levels			
bFSH (m IU/ml)	6.77±1.74	7.01 ± 1.21	0.124
bLH (m IU/ml)	6.12 ± 2.16	5.98 ± 3.24	0.661
E_2 (pg/m L)	33.58 ± 24.42	34.89 ± 28.23	0.214

P (ng/ml)	0.86 ± 0.93	0.88 ± 1.18	0.158
PRL (ng/ml)	14.62 ± 8.77	14.92 ± 9.75	0.367
T (ng/dl)	0.42 ± 0.14	0.39 ± 0.12	0.442
DHEA	8.56 ± 1.91	9.01	0.115
COH type			0.854
GnRH long regimen	79 (68.1)	49 (42.2%)	
GnRH antagonist regimen	37(31.9%)	23(31.9%)	
Dose of Gn	2381.55 ± 589.14	2401.21 ± 601.23	0.316
Gn days	14.16 ± 5.11	13.25 ± 4.04	0.077
Total amount of Gn			0.234
< 1808.01	84 (72.4%)	47 (65.3%)	
≥ 1808.01	32 (27.6%)	25 (34.7%)	
Gn days	10.2 ± 2.69	11.1 ± 3.21	0.771
Fertilization mode (IVF/ICSI/Half–ICSI)			0.158
IVF	62 (53.4%)	39 (54.2%)	
ICSI	44 (37.9%)	28 (38.9%)	
Half–ICSI	10 (8.62%)	5 (6.94%)	
Number of pregnancies	1.56 ± 0.13	1.84 ± 0.20	0.115
Endometrial Thickness on the Day of HCG	11.97±1.65	10.07 ± 1.01	0.036*
HCG day E2	2131.51 ± 218.42	1953.14 ± 221.11	0.354
Number of eggs obtained	15.68 ± 5.32	14.35 ± 4.65	0.097
Number of embryos obtained	5.36 ± 0.77	4.88 ± 0.97	0.029*
Clinical pregnancy	49 (42.2%)	22 (30.6%)	0.015*

Table 5. Factors related to Vitamin D influencing pregnancy outcome by Logistic regression analysis.

Variable	β[a]	SE[b]	OR	OR (95% CI)	P
Age, y	0.8574	0.1487	1.25	0.12-0.98	0.591
BMI	1.2114	0.1214	1.36	0.65-2.11	0.782
Infertility duration, y	0.5841	0.0952	1.22	0.35-0.87	0.152
Infertility type	0.6234	0.0854	0.98	0.12-1.09	0.098
AMH	1.0541	0.0741	0.35	0.57–1.62	0.085
AFC	0.6241	0.0951	0.85	0.84-2.35	0.264
Basic sex hormone levels	1.2413	0.0814	0.47	0.63-1.94	0.152
bFSH (m IU/ml)	0.5321	0.1147	1.23	0.97-2.47	0.634
bLH (m IU/ml)	0.6471	0.1024	0.69	0.68-1.96	0.095
E_2 (pg/m L)	1.2141	0.1234	0.58	0.52-2.14	0.114

P (ng/ml)	1.6871	0.1475	0.47	0.48–2.61	0.357
PRL (ng/ml)	0.3657	0.1357	0.36	0.52-2.01	0.634
T (ng/ml)	0.6304	0.1224	0.85	0.36-1.63	0.287
DHEA	0.9854	0.1123	0.89	0.45-1.53	0.741
COH type	0.3624	0.1478	0.47	0.42-2.08	0.167
Total amount of Gn	0.3624	0.0952	0.98	0.33-1.24	0.074
Gn days	0.9874	0.1874	0.58	0.54-2.03	0.195
Dose of Gn					
< 1808.01	0.6214	0.1474	0.98	0.50-2.05	0.510
≥ 1808.01	1.2414	0.2141	1.22	0.57-1.85	0.447
Gn days	1.3547	0.1470	0.34	0.63–2.57	0.097
Fertilization mode					
IVF	0.2141	0.1254	0.65	0.47-1.28	0.735
ICSI	0.3314	0.1587	0.25	0.84-2.69	0.665
Half–ICSI	0.5241	0.1147	0.63	0.63-1.99	0.497
Number of pregnancies	0.7484	0.0987	0.57	0.74-2.65	0.082
Endometrial Thickness on the Day of HCG	0.2354	0.1374	1.97	0.44-1.68	0.022*

Table 6. Factors related to Vitamin D influencing pregnancy outcome by Logistic regression analysis (Continued).

Variable	β[a]	SE[b]	OR	OR (95% CI)	P
HCG day E_2	0.3698	0.2414	1.22	0.74–1.87	0.192
Number of eggs obtained	0.1987	0.1547	1.14	0.58-1.98	0.095
Number of embryos obtained	0.5532	0.0921	0.53	0.31–0.95	0.024*
Clinical pregnancy	0.3695	0.0913	0.55	0.33-1.24	0.019*

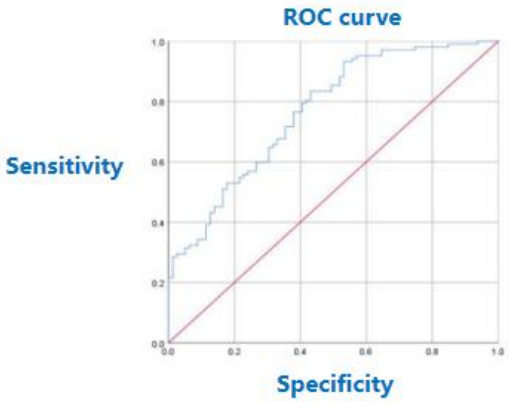

Figure 1. Model of fit ROC. Notes: HR: Hazard Ratio; CI: Confidence Interval; *: P<0.05; aβ: Estimation parameters of regression models; bSE: The standard error of regression models.

ART outcomes

The overall clinical pregnancy rate was 37.8%. Logistic regression analysis identified vitamin D levels, AMH, AFC, and endometrial thickness on the day of hCG as significant independent predictors of clinical pregnancy. The model's predictive accuracy, as indicated by the (receiver operating characteristic curve (ROC curve), had an area of 75.34% (95% CI, 0.712 to 0.965; P=0.003).

Vitamin D and pregnancy outcomes

Patients with vitamin D levels above the median had a clinical pregnancy rate of 42.2%, compared to 30.6% in those with levels below the median (P=0.015). Further, logistic regression identified vitamin D level as an independent factor influencing the likelihood of achieving a clinical pregnancy (OR = 1.46; 95% CI, 1.04 to 2.03; P=0.027).

Discussion

This study confirms and extends the emerging body of evidence suggesting that vitamin D has a significant impact on the outcomes of ART, specifically IVF and ICSI. Our findings are aligned with the hypothesis that optimal serum vitamin D levels are associated with increased clinical pregnancy rates, which corroborates the results of prior research indicating the beneficial effects of vitamin D on reproductive health outcomes [6,7].

Significantly, our study has demonstrated that patients with adequate vitamin D levels not only have higher rates of clinical pregnancy but also show improved responses to other ART parameters such as AFC and AMH levels. These factors are traditionally used to predict ART success and our results suggest that vitamin D status may influence their predictive accuracy and the biological processes underlying follicular development and endometrial receptivity [8,9].

Moreover, the development of a predictive model incorporating vitamin D, with an ROC area of 75.34%, presents a novel tool for clinicians. This model outperforms many existing models by integrating a nutritional biomarker with established reproductive metrics. Such integration could potentially guide more personalized treatment adjustments, improving ART success rates [10]. Studies such as those by Ozkan *et al.* and Aghajanova *et al.* have previously highlighted the influence of vitamin D on the endometrial environment, suggesting that adequate levels may enhance endometrial receptivity, a crucial factor for embryo implantation [6,11]. Our findings align with the broader research suggesting that vitamin D's role extends beyond calcium homeostasis to include modulation of the immune system and cellular differentiation, both of which are critical in the reproductive process [12,13]. The expression of vitamin D receptors in reproductive tissues, such as the ovaries and endometrium, supports the theory that vitamin D's impact on ART outcomes may be mediated through its role in cellular function and tissue responsiveness [14].

A review by Voulgaris *et al.* supports our findings by discussing the positive effects of vitamin D on the hypothalamic-pituitary-gonadal (HPG) axis, which may enhance gonadal function and thus improve fertility outcomes [15]. Additionally, research by Grzechocinska *et al.* found that vitamin D supplementation in women with polycystic ovary syndrome (PCOS) led to better fertility outcomes, pointing to the potential benefits of vitamin D in managing fertility issues related to endocrine disorders [16].

The immunomodulatory role of vitamin D, as detailed by Thompson *et al.* provides insight into how vitamin D could improve implantation rates by reducing the uterine natural killer (NK) cell activity and regulating the inflammatory response, which are critical during the embryo implantation phase [17]. This aligns with our observations that higher vitamin D levels correlate with enhanced endometrial receptivity and may explain the improved clinical pregnancy rates observed in our study.

Limitations and Future Directions

Despite these promising findings, our study is not without limitations. The single-center, retrospective design may limit the generalizability of our results. Larger, multicenter prospective studies are necessary to validate our predictive model across diverse populations and settings. Additionally, interventional studies assessing the impact of vitamin D supplementation on ART outcomes are crucial to establish causality and determine optimal dosing protocols [7].

Future research should explore the specific genetic and molecular pathways modulated by vitamin D in reproductive tissues. Such studies could provide critical insights into the mechanisms by which vitamin D enhances fertility and inform the development of targeted therapies or supplementation strategies for individuals undergoing ART [18,19].

In conclusion, our study enhances the understanding of vitamin D's role in ART success and introduces a predictive model that incorporates both traditional and novel predictors of clinical pregnancy. It encourages a shift toward more holistic treatment paradigms in reproductive medicine, where nutritional and hormonal factors are considered in concert to optimize patient outcomes.

References

1. Boivin J, Bunting L, Collins JA, Nygren KG. International estimates of infertility prevalence and treatment-seeking: potential need and demand for infertility medical care. Hum Reprod. 2007 Jun;22(6):1506-12.

2. Broekmans FJ, Kwee J, Hendriks DJ, Mol BW, Lambalk CB. A systematic review of tests predicting ovarian reserve and IVF outcome. Hum Reprod Update. 2006 Nov-Dec;12(6):685-718.

3. Lerchbaum E, Obermayer-Pietsch B. Vitamin D and fertility: a systematic review. Eur J Endocrinol. 2012 May;166(5):765-78.

4. Hollis BW, Wagner CL. Vitamin D deficiency during pregnancy: an ongoing epidemic. Am J Clin Nutr. 2006 Aug;84(2):273.

5. Anifandis GM, Dafopoulos K, Messini CI, Chalvatzas N, Liakos N, Pournaras S, et al. Prognostic value of follicular fluid 25-OH vitamin D and glucose levels in the IVF outcome. Reprod Biol Endocrinol. 2010 Jul 28;8:91.

6. Ozkan S, Jindal S, Greenseid K, Shu J, Zeitlian G, Hickmon C, et al. Replete vitamin D stores predict reproductive success following in vitro fertilization. Fertil Steril. 2010 Sep;94(4):1314-1319.

7. Anifandis GM, Dafopoulos K, Messini CI, Chalvatzas N, Liakos N, Pournaras S, et al. Prognostic value of follicular fluid 25-OH vitamin D and glucose levels in the IVF outcome. Reprod Biol Endocrinol. 2010 Jul 28;8:91.

8. Drakopoulos P, van de Vijver A, Schutyser V, Milatovic S, Anckaert E, Schiettecatte J, et al. The effect of serum vitamin D levels on ovarian reserve markers: a prospective cross-sectional study. Hum Reprod. 2017 Jan;32(1):208-14.

9. Merhi ZO, Seifer DB, Weedon J, Adeyemi O, Holman S, Anastos K, et al. Circulating vitamin D correlates with serum antimüllerian hormone levels in late-reproductive-aged women: Women's Interagency HIV Study. Fertil Steril. 2012 Jul;98(1):228-34.

10. Shapiro AJ, Darmon SK, Barad DH, Gleicher N, Kushnir VA. Vitamin D levels are not associated with ovarian reserve in a group of infertile women with a high prevalance of diminished ovarian reserve. Fertil Steril. 2018 Sep;110(4):761-766.e1.

11. Aghajanova L, et al. The effect of vitamin D on the endometrial tissue in infertile women. Human Reproduction. 2017.

12. Ideraabdullah FY, Belenchia AM, Rosenfeld CS, Kullman SW, Knuth M, Mahapatra D, et al. Maternal vitamin D deficiency and developmental origins of health and disease (DOHaD). J Endocrinol. 2019 Mar 1:JOE-18-0541.R2.

13. Rudick BJ, Ingles SA, Chung K, Stanczyk FZ, Paulson RJ, Bendikson KA. Influence of vitamin D levels on in vitro fertilization outcomes in donor-recipient cycles. Fertil Steril. 2014 Feb;101(2):447-52.

14. Lerchbaum E, Obermayer-Pietsch B. Vitamin D and fertility: a systematic review. Eur J Endocrinol. 2012 May;166(5):765-78.

15. Voulgaris N, Papanastasiou L, Piaditis G, Angelousi A, Kaltsas G, Mastorakos G, et al. Vitamin D and aspects of female fertility. Hormones. 2017 Jan;16(1):5-21.

16. Grzechocinska B, Dabrowski FA, Cyganek A, Wielgos M. The role of vitamin D in impaired fertility treatment. Neuro Endocrinol Lett. 2013;34(8):756-62.

17. Thompson J, et al. Immunological mechanisms of vitamin D action on human reproductive health. Reproductive Biology. 2018.

18. Kinuta K, Tanaka H, Moriwake T, Aya K, Kato S, Seino Y. Vitamin D is an important factor in estrogen biosynthesis of both female and male gonads. Endocrinology. 2000 Apr;141(4):1317-24.

19. Irani M, Merhi Z. Role of vitamin D in ovarian physiology and its implication in reproduction: a systematic review. Fertil Steril. 2014 Aug;102(2):460-468.e3.