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Investigating Vitamin D Awareness, Supplementation Practices, and Perceived Infertility Risk in Derna and Tobruk: A Cross-Sectional Study Integrating Pharmacy and Gynaecology Perspectives

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ABSTRACT

Infertility is an increasing public health concern in Libya, intensified by the high prevalence of vitamin D insufficiency and related behavioural gaps among women of reproductive age. Although international evidence highlights associations between vitamin D insufficiency, ovulatory dysfunction, implantation failure, and polycystic ovary syndrome, region-specific research in North Africa remains limited. This cross-sectional study investigated the association between vitamin D awareness, supplementation practices, and self-reported infertility experiences among 1,000 women in Derna and Tobruk between March 2024 and May 2025, with emphasis on pharmacy and gynaecological practices. Data were collected through structured questionnaires measuring demographic characteristics, vitamin D awareness, infertility experiences, and professional practices, and were analysed using SPSS v29 with Pearson's correlation, independent t-tests, and multiple regression. Results demonstrated that women recognised the role of vitamin D in reproductive health, yet regular supplementation and dietary intake were limited. A significant association was observed between lower vitamin D awareness and practices and higher self-reported infertility experiences ($r = 0.42$, $OR = 1.53$, $p < 0.001$). Pharmacists contributed more to supplement provision, while gynaecologists prioritised diagnostic testing. Systemic barriers such as cost, limited laboratory facilities, and weak professional collaboration strongly influenced infertility perceptions. Findings reflect reported perceptions and practices rather than biochemical measurement of serum vitamin D levels, underscoring the need for clearer clinical guidelines, affordable screening, and enhanced cooperation between pharmacists and gynaecologists to strengthen reproductive health care in eastern Libya.

Keywords: Vitamin D awareness, supplementation practices, self-reported infertility, pharmacy practice, gynaecology, reproductive health, Libya.

استقصاء الوعي بفيتامين (د) وممارسات المكملات الغذائية وعلاقتها المدركة بالعقم في درنة وطبرق: دراسة مقطعية تدمج المنظورين الصيدلاني والنسائي

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ملخـــــص البحـــــث

يمثل العقم تحدياً متزايداً للصحة العامة في ليبيا، ويزداد حدة مع الانتشار الواسع لـ نقص الوعي ومحدودية الممارسات المرتبطة بفيتامين (د) بين النساء في سن الإنجاب. ورغم أن الأدلة الدولية تربط نقص فيتامين (د) باضطرابات الإباضة

وفشل الانغراس ومتلازمة تكيس المبايض، فإن الأبحاث الإقليمية في شمال أفريقيا ما تزال محدودة. هدفت هذه الدراسة المقطعية إلى استقصاء العلاقة بين الوعي بفيتامين (د) وممارسات استخدامه وتجارب العقم المبلغ عنها ذاتياً لدى 1000 امرأة في مدينتي درنة وطبرق بين مارس 2024 ومايو 2025، مع التركيز على الممارسات الصيدلانية والنسائية. جُمعت البيانات باستخدام استبيان منظم شمل الخصائص الديموغرافية، الوعي بفيتامين (د)، تجارب العقم، والممارسات المهنية، وحُللت بواسطة برنامج SPSS v29 باستخدام معاملات الارتباط واختبارات (t) والانحدار المتعدد. أظهرت النتائج إدراكاً عالياً لدور فيتامين (د) في الصحة الإنجابية، لكن الالتزام بالمكملات الغذائية ظل منخفضاً .وأظهر التحليل وجود ارتباط ذي دلالة إحصائية بين انخفاض الوعي والممارسات المرتبطة بفيتامين (د) وزيادة تجارب العقم المبلغ عنها ذاتياً ($r = 0.42$)، $OR = 1.53$، ($p < 0.001$). انخرط الصيادلة أكثر في توفير المكملات، بينما اعتمد الأطباء على الفحوصات التشخيصية. كما أثرت العوائق النظامية مثل التكلفة وضعف المختبرات وضعف التنسيق المهني بشكل واضح في إدراك العقم .تعكس هذه النتائج الإدراكات والممارسات المبلغ عنها ذاتياً ولا تمثل قياساً بيوكيميائياً مباشراً لمستويات فيتامين (د) في الدم، مما يبرز الحاجة إلى وضع إرشادات إكلينيكية أوضح، وتوسيع الفحوصات بأسعار مناسبة، وتعزيز التعاون بين الصيادلة وأطباء النساء لدعم رعاية الصحة الإنجابية في شرق ليبيا.

الكلمات المفتاحية: الوعي بفيتامين (د)، ممارسات المكملات الغذائية، العقم المبلغ عنه ذاتياً، الممارسة الصيدلانية، طب النساء، الصحة الإنجابية، ليبيا.

1. Introduction

Infertility is widely recognised as a pressing global health concern, with approximately 48.5 million couples affected worldwide [1]. The consequences extend beyond biological challenges, encompassing psychological distress and substantial socio-economic implications. Nutritional status, particularly vitamin D, has emerged as an important factor shaping reproductive health outcomes. "Vitamin D deficiency and female infertility: a mechanism review examining the role of vitamin D in ovulatory dysfunction as a symptom of polycystic ovary syndrome" highlights the importance of deficiency in impairing ovulatory function, endometrial receptivity, and subsequent fertility [1]. Such mechanistic insight underscores the plausibility that inadequate vitamin D levels influence follicular development and implantation. The recognition that modifiable nutritional factors may influence reproductive success reinforces the rationale for examining vitamin D deficiency in relation to infertility in populations where deficiency is highly prevalent and services for fertility management are limited.

Vitamin D functions as a steroid hormone, with active metabolites acting on receptors in reproductive tissues including the ovary, endometrium, and placenta [2, 3]. The hormone regulates expression of implantation-related genes such as HOXA10 [4], while deficiency has been associated with impaired granulosa cell proliferation and reduced follicular maturation. Observational studies demonstrate a strong link between polycystic ovary syndrome and vitamin D deficiency, with reduced ovulation and lower live birth rates among affected women [5]. The mechanism is thought to involve disruption of insulin sensitivity and promotion of low-grade chronic inflammation, both common features of PCOS [6]. The biological plausibility linking vitamin D deficiency with infertility is further supported by immune-modulatory effects, where vitamin D influences macrophages, natural killer cells, and dendritic cells, processes important for successful implantation [7].

Epidemiological findings support this association. Zhao, Fu and Chen [2] demonstrated, using NHANES data, that women in the lowest vitamin D quartile had markedly higher odds of both general obesity (OR = 8.29) and abdominal obesity (OR = 4.82). Given that obesity independently reduces reproductive success, the combined effect of vitamin D deficiency and adiposity provides a critical pathway for understanding infertility risk. Methodological limitations, such as self-reported infertility status and the absence of fertility-specific hormonal measures, reduce the strength of interpretation, but the evidence nonetheless indicates a consistent inverse association between serum vitamin D and infertility risk factors. Intervention trials add further complexity. In animal experiments, supplementation with vitamin D3 induced decidualisation of rat endometrial cells [8]. In human studies, supplementation has sometimes improved in vitro fertilisation outcomes [9, 10], but other investigations report no effect [11, 12]. A systematic review and meta-analysis confirmed that supplementation significantly increased clinical pregnancy rates (OR 1.70, 95% CI 1.24–2.34), though effects on implantation, miscarriage, and multiple pregnancies were not significant [13]. Importantly, the review showed that baseline vitamin D status, dosage, and regimen influenced outcomes, reflecting considerable heterogeneity across studies.

Variation in definitions of deficiency complicates interpretation. The Institute of Medicine defines deficiency as serum 25(OH)D below 30 nmol/L, while other authorities classify <50 nmol/L as deficient, with 50–75 nmol/L considered insufficient or sufficient depending on criteria [14]. Around 40% of Europeans are reported to have inadequate vitamin D levels [15], while deficiency in Middle Eastern and North African populations is more pronounced due to restricted sun exposure from clothing norms, limited dietary intake, and absence of supplementation policies [16]. Libya shares these risk factors, yet there is little published evidence quantifying deficiency or investigating its reproductive implications. Regional variations in sunlight exposure and healthcare access make local research critical. Without population-specific data, the application of global evidence remains limited and potentially misleading for clinical and public health interventions in Libya.

The Libyan setting presents a distinct gap. Derna and Tobruk, urban centres in the east of the country, face rising rates of infertility and fragmented reproductive health services. Vitamin D testing is not routine, and supplementation practices are inconsistent. Pharmacists often act as frontline providers of vitamin D supplements, yet collaboration with gynaecologists is minimal, resulting in fragmented patient counselling and management. No cross-sectional studies in Libya have examined the association between vitamin D deficiency and infertility, nor has research integrated both pharmacy and gynaecology perspectives. Addressing this evidence gap will enable clearer understanding of both biomedical associations and systemic barriers. Survey-based methods that incorporate patient experiences and professional perspectives provide an opportunity to identify deficiencies in service delivery and inform context-appropriate recommendations. By focusing on Derna and Tobruk, the study offers an opportunity to generate the first region-specific evidence to guide reproductive health practice and policy.

The aim of the study is to investigate the association between vitamin D deficiency and infertility among women in Derna and Tobruk, with particular attention to the roles of pharmacy practice and gynaecological perspectives in patient care. The first objective is to determine the

prevalence of vitamin D deficiency among women of reproductive age in Derna and Tobruk and its association with self-reported infertility. The second objective is to assess knowledge, attitudes, and practices relating to vitamin D supplementation among pharmacists and gynaecologists involved in fertility care. The third objective is to identify healthcare system barriers influencing diagnosis, supplementation, and counselling practices in relation to vitamin D deficiency and infertility. The study is expected to generate the first region-specific evidence linking vitamin D deficiency with infertility in Libya. Findings will inform culturally appropriate reproductive health strategies, integrating pharmacy and gynaecology practices. Outcomes are expected to provide practical recommendations for improving supplementation guidelines and patient counselling in North African healthcare systems. Based on these aims, three hypotheses are proposed. First, vitamin D deficiency will be significantly associated with higher rates of self-reported infertility among women of reproductive age in Derna and Tobruk. Second, pharmacists and gynaecologists will demonstrate limited but differing levels of knowledge and practices regarding vitamin D supplementation in infertility management. Third, systemic barriers including lack of diagnostic screening, weak inter-professional collaboration, and inconsistent supplementation protocols will negatively influence the effective management of infertility linked to vitamin D deficiency.

2. Methods

2.1 Research Design

The study employed a quantitative cross-sectional survey design using a structured questionnaire. A cross-sectional approach was chosen as it allows data collection on vitamin D awareness, **perceived deficiency-related risk**, infertility experiences, and professional practices at a single point in time, offering **estimation of associations rather than causal relationships or true epidemiological prevalence** [17]. This design is cost-effective, feasible within time constraints, and particularly suitable for public health research in middle-income contexts where baseline evidence is scarce [18]. Cross-sectional surveys have been widely applied in reproductive health research to examine nutritional and clinical factors influencing infertility, making the design appropriate for this investigation in Libya [19]. **However, it is explicitly acknowledged that this design does not permit causal inference or classification of vitamin D deficiency as a biological risk factor, but rather enables examination of reported associations between variables.**

2.2 Participants

Eligible participants were women of reproductive age (18–45 years) residing in Derna or Tobruk. Women attending reproductive health or pharmacy-based services were included if they could read Arabic, provided informed consent, and were willing to participate voluntarily. Both women with and without self-reported infertility were included to capture comparative responses. Exclusion criteria applied to women with severe medical conditions requiring hospitalisation, those unable to complete the questionnaire due to literacy or cognitive barriers, and healthcare professionals or medical students to avoid professional knowledge bias. These criteria ensured that the sample represented typical service users of reproductive and pharmacy care in north-east Libya. **Infertility in this study was operationalised as self-reported infertility experiences based on difficulty conceiving for at least one year, rather than a**

confirmed clinical diagnosis, and this distinction was explicitly recognised during analysis and interpretation.

2.3 Study Setting

Data were collected across six facilities in Derna and Tobruk between March 2024 and May 2025. In Derna, recruitment took place in Al-Wehda Primary Health Centre, Al-Fateh Polyclinic, and Martyrs' PHC, while in Tobruk, data were collected from Tobruk Central PHC, Al-Salam PHC, and Al-Manara PHC. These centres were selected due to their high patient volume, established reproductive health services, and accessibility to women from varied socio-economic backgrounds. Collaboration with the Faculty of Pharmacy at Tobruk University enabled the integration of pharmacy and gynaecological perspectives, ensuring representation of both clinical and pharmaceutical domains in the survey**. The extended data collection period was necessary to achieve the target sample size across multiple facilities and to accommodate variability in patient attendance, ensuring minimal disruption to healthcare service delivery.**

2.4 Sampling Technique and Sample Size

A convenience sampling technique was adopted, as it allowed efficient recruitment of women attending clinics and pharmacies during the data collection period [20]. Although this method does not provide full representativeness, it is frequently used in reproductive health research where registry-based sampling frames are unavailable. The final sample comprised 1,000 participants, equally divided between Derna (n = 500) and Tobruk (n = 500). The sample size was determined using prevalence estimates from regional studies, with a 95% confidence level and 5% margin of error. This number was sufficient to detect significant associations across **vitamin D awareness, supplementation practices, and perceived infertility experiences**, while also enabling subgroup analyses across cities. **It is important to note that the sample size supports analysis of associations within the surveyed population rather than estimation of population-level prevalence of vitamin D deficiency.**

2.5. Recruitment Process

Recruitment was carried out in waiting areas of participating health centres and pharmacies. Women meeting the inclusion criteria were approached by trained data collectors, who provided an oral explanation of the study in Arabic alongside an information sheet. Written informed consent was obtained prior to participation. Participants then completed a paper-based questionnaire, either independently or with assistance if literacy barriers were identified. The questionnaire was pre-tested with 30 women from both cities to ensure clarity, cultural appropriateness, and smooth flow, with minor revisions made before full-scale data collection. Trained pharmacy and gynaecology staff supported the process to ensure reliability and minimise disruption to clinical workflows.

2.6 Questionnaire Instrument

The questionnaire employed in this study was systematically designed to investigate the association between **vitamin D awareness, perceived deficiency-related risk, and supplementation practices** and infertility among women of reproductive age in Derna and Tobruk, Libya, with additional perspectives from pharmacists and gynaecologists. The instrument was structured into five distinct scales, developed in alignment with the study's aims

and informed by prior empirical studies on vitamin D, infertility, and reproductive health [1, 2, 15].

Scale 1 – Demographic and Socioeconomic Profile Scale (DSPS) captured essential participant characteristics. Variables included age, education level, monthly household income, marital status, occupation, parity, and city of residence. These variables were chosen to reflect potential influences on **vitamin D-related behaviours and infertility experiences**, as sociodemographic status is a recognised determinant of both nutritional practices and access to reproductive health services [2].

Scale 2 – Vitamin D Awareness and Deficiency (VDAD Scale) served as a dependent variable scale comprising six Likert-type items. This scale assessed knowledge of vitamin D's role in reproductive health, awareness of deficiency risks, supplement-taking practices, and perceptions of sunlight and diet as sources. Items such as "I believe vitamin D deficiency increases the risk of infertility" and "I have received advice about vitamin D testing from healthcare professionals" were included, reflecting constructs highlighted in earlier mechanistic and clinical studies [1, 15]. **It is important to note that this scale does not measure biochemical vitamin D status (e.g., serum 25(OH)D), but rather reflects participants' awareness, perceptions, and reported practices related to vitamin D.**

Scale 3 – Infertility Experiences and Perceptions (IEP Scale) functioned as the second dependent variable scale and included eight items. Questions addressed self-reported infertility, emotional distress, medical consultations, laboratory testing, and attitudes towards vitamin D supplementation in relation to infertility. For example, "I have experienced difficulty conceiving despite regular attempts over one year" and "I would consider vitamin D supplementation as part of infertility treatment" captured both personal and behavioural dimensions. These variables were guided by epidemiological studies linking vitamin D to infertility and its psychosocial implications [2]. **Infertility in this study was defined as a self-reported experience rather than a clinically confirmed diagnosis, and no hormonal, male-factor, or specialist diagnostic assessments were included.**

Scale 4 – Pharmacy and Gynaecology Practices (PGP Scale) examined professional practices and systemic barriers in fertility care. This eight-item scale assessed pharmacists' counselling, gynaecologists' diagnostic approaches, inter-professional collaboration, and patient reliance on pharmacy advice. Statements such as "Pharmacists provide adequate counselling about vitamin D supplementation" and "There is effective communication between pharmacists and gynaecologists in patient care" reflected knowledge gaps and structural challenges identified in reproductive health systems in low- and middle-income countries [15]. **Responses within this scale represent participants' perceptions of professional roles and practices, rather than direct data collected from pharmacists or gynaecologists themselves.**

Scale 5 – Supporting Attitudinal and Behavioural Scales (SABS) included two standardised 5-item subscales. The Health Behaviour Subscale assessed diet, physical activity, health check-ups, and supplementation adherence, while the Infertility Stigma Subscale evaluated social pressure, marital tensions, and community perceptions of infertility. These dimensions were incorporated to capture broader behavioural and psychosocial correlates of infertility risk and care-seeking.

The questionnaire was administered in Arabic and translated from English using forward–backward translation to ensure conceptual equivalence. It was pre-tested with a sample of 30 women, pharmacists, and gynaecologists across Derna and Tobruk to assess linguistic clarity, cultural appropriateness, and item comprehension. Final revisions were made to improve readability, flow, and contextual alignment with Libyan reproductive health services. Informed consent was obtained from all participants prior to data collection. Data were collected across major healthcare and pharmacy outlets in Derna and Tobruk, including Al-Wahda Hospital, Tobruk Medical Centre, and community pharmacies, over a 12-month period from June 2024 to July 2025.

2.7 Measurement Validity and Reliability

To ensure psychometric validity, each scale was developed from established constructs in prior studies on vitamin D, infertility, and reproductive health [1, 2, 15]. Internal consistency was tested using Cronbach's alpha (α), with all Likert-based scales surpassing 0.70, confirming reliability. Convergent validity was assessed using Average Variance Extracted (AVE), with all scales meeting the >0.50 benchmark. These measures confirmed that the questionnaire accurately captured knowledge, attitudes, experiences, and professional practices regarding vitamin D and infertility in the Libyan context.

Table Table 1. Reliability and Validity Summary of the Vitamin D and Infertility Questionnaire

Scale Name	Number of Items	Cronbach's Alpha (α)	Average Variance Extracted (AVE)	Construct Interpretation
Vitamin D Awareness and Deficiency (VDAD)	6	0.81	0.55	Measures awareness, perceptions, and supplementation practices related to vitamin D rather than biochemical serum levels
Infertility Experiences & Perceptions (IEP)	8	0.84	0.57	Captures self-reported infertility experiences and psychosocial perceptions, not clinically confirmed infertility diagnosis
Pharmacy & Gynaecology Practices (PGP)	8	0.83	0.56	Reflects participants' perceptions of professional roles and system-level practices rather than direct provider data
Health Behaviour Subscale	5	0.79	0.53	Assesses general lifestyle behaviours influencing health and supplementation adherence
Infertility Stigma Subscale	5	0.82	0.58	Evaluates perceived social and psychological dimensions of infertility within the community

These results confirm that all scales demonstrate acceptable internal consistency and convergent validity, while also indicating that the instrument measures perception-based and behavioural

constructs rather than objective clinical or biochemical indicators.

3.8 Ethical Considerations

The study followed ethical standards for research involving human participants. Ethical approval was obtained from the Research Ethics Committee at the Faculty of Pharmacy, Tobruk University. All participants were provided with informed consent forms in Arabic outlining study objectives, voluntary participation, confidentiality, and absence of medical risks. Participation involved completing a structured questionnaire only, with no clinical intervention. Anonymity was preserved by excluding identifying information, and responses were securely stored. The design minimised participant burden and adhered to national and institutional ethical guidelines for health-related research in Libya.

2.9 Data Analysis Techniques

Data were analysed using IBM SPSS Statistics version 29, with composite scores generated for each Likert-based scale and normality assessed through the Shapiro–Wilk and Kolmogorov–Smirnov tests, both confirming suitability for parametric testing. The first hypothesis, examining the association between vitamin D deficiency (VDAD scale) and infertility experiences (IEP scale), was tested using Pearson's correlation and logistic regression. **These analyses were interpreted as associations between perception-based variables rather than evidence of a causal relationship or confirmed biological deficiency.**

The second hypothesis, evaluating knowledge and practice differences between pharmacists and gynaecologists (PGP scale), was examined using independent t-tests. **This comparison reflects perceived differences in roles based on participant responses, not direct comparisons between healthcare professionals.** The third hypothesis, assessing systemic barriers (PGP scale) as predictors of infertility experiences (IEP scale), was analysed through multiple regression. Reliability was confirmed by Cronbach's alpha, with all scales demonstrating strong internal consistency, and statistical significance was determined at $p < 0.05$ with 95% confidence intervals.

3. Findings

3.1 Participant Characteristics

Table 2 presents the demographic characteristics of participants (n = 1,000), equally recruited from Derna (n = 500) and Tobruk (n = 500). The sample consisted of women of reproductive age attending healthcare and pharmacy settings in both cities. Age distribution indicated that the largest group was between 25–29 years (30%), followed by 30–34 years (25%), 20–24 years (20%), 35–39 years (15%), and those aged 40 years or older (10%). Educational attainment showed that 34% had completed secondary education, 26% held diplomas, 26% reported bachelor's degrees, and 14% reported postgraduate qualifications.

Employment status revealed that 42% were unemployed (housewives), 22% worked as government employees, 14% in private sector roles, 12% as skilled workers, and 10% in unskilled occupations. Household income patterns indicated that 16% of participants reported less than 1,000 LYD per month, 30% earned between 1,000–3,000 LYD, and 24% earned above 3,000 LYD, with marked variability across both cities. In relation to infertility duration, 18% had been trying to conceive for less than one year, 26% reported 1–3 years, and 14% reported more than three years. **The remaining 42% of participants were classified as having no**

history of infertility or not applicable to this variable, and this category has been clarified to ensure that total percentages sum to 100%.

Marital status data showed that the overwhelming majority were married (92%), with smaller proportions identifying as divorced (5%) or widowed (3%). Residency was balanced, with 500 participants drawn from each city to ensure comparability. The sample was overwhelmingly Libyan (97%), with only 3% reporting non-Libyan nationality. These findings highlight the diversity of socioeconomic and educational backgrounds represented, while also confirming that infertility concerns cut across all social groups in both Derna and Tobruk.

Table 2. Demographic Characteristics of Participants (n = 1,000)

Variable	Category	Frequency (n)	Percentage (%)
Age Group	20–24	200	20.0%
	25–29	300	30.0%
	30–34	250	25.0%
	35–39	150	15.0%
	40 and above	100	10.0%
Educational Level	Secondary	340	34.0%
	Diploma	260	26.0%
	Bachelor's	260	26.0%
	Postgraduate	140	14.0%
Occupation	Unemployed (housewife)	420	42.0%
	Skilled worker	120	12.0%
	Unskilled worker	100	10.0%
	Government employee	220	22.0%
	Private sector	140	14.0%
Monthly Household Income	Less than 1,000 LYD	160	16.0%
	1,000–3,000 LYD	300	30.0%
	More than 3,000 LYD	240	24.0%
Infertility Duration	<1 year	180	18.0%
	1–3 years	260	26.0%
	>3 years	140	14.0%
Marital Status	Married	920	92.0%
	Divorced	50	5.0%
	Widowed	30	3.0%
Residency	Derna	500	50.0%
	Tobruk	500	50.0%
Nationality	Libyan	970	97.0%
	Non-Libyan	30	3.0%

3.2 Section B: Vitamin D Awareness and Infertility Experiences

Table 3 presents responses on the Vitamin D Awareness and Deficiency (VDAD) Scale (6 items) and the Infertility Experiences and Perceptions (IEP) Scale (8 items). A total of 1,000 participants completed both scales. High mean agreement was noted for awareness of vitamin

D's role in reproductive health (M = 4.2, SD = 0.7) and the perception that deficiency increases infertility risk (M = 4.0, SD = 0.8). By contrast, regular supplementation (M = 2.9, SD = 0.9) and dietary source consideration (M = 3.0, SD = 1.0) received lower means, indicating gaps in practice. Within the IEP scale, participants strongly endorsed infertility as emotionally distressing (M = 4.3, SD = 0.6) and socially stigmatised (M = 4.1, SD = 0.7). Lower mean scores were observed for the use of assisted reproductive technologies (M = 2.8, SD = 0.9) and laboratory testing uptake (M = 3.2, SD = 0.8). Variation across items suggests that while awareness and perceived risks are relatively high, access to diagnosis and treatment remains limited. It is important to note that infertility in this study is based on self-reported experiences rather than clinically confirmed diagnoses, and therefore findings should be interpreted within this context.

Table 3. Vitamin D Awareness and Infertility Experiences (n = 1,000 participants)

Scale	Item No.	Statement	Mean ± SD
VDAD	1	I am aware that vitamin D plays a role in reproductive health.	4.2 ± 0.7
	2	Sunlight exposure is sufficient for maintaining vitamin D levels in my community.	3.5 ± 0.9
	3	I have received advice about vitamin D testing from healthcare professionals.	3.6 ± 0.8
	4	I believe vitamin D deficiency increases the risk of infertility.	4.0 ± 0.8
	5	I regularly take vitamin D supplements (capsules, drops, or injections).	2.9 ± 0.9
	6	I consider dietary sources of vitamin D (e.g. fish, fortified milk) as important for fertility.	3.0 ± 1.0
IEP	1	I have experienced difficulty conceiving despite regular attempts over one year.	3.8 ± 0.8
	2	Infertility is a significant source of emotional distress in my life.	4.3 ± 0.6
	3	I believe infertility in my community carries social stigma.	4.1 ± 0.7
	4	I have sought medical consultation for infertility.	3.4 ± 0.9
	5	I have undergone laboratory tests related to infertility.	3.2 ± 0.8
	6	I have used or considered assisted reproductive technologies (e.g. IVF).	2.8 ± 0.9
	7	I believe infertility in my case may be linked to vitamin D deficiency.	3.6 ± 0.7
	8	I would consider vitamin D supplementation as part of infertility treatment.	3.9 ± 0.8

3.3 Section C: Pharmacy–Gynaecology Practices, Health Behaviour, and Infertility Stigma

Table 4 summarises findings from the Pharmacy and Gynaecology Practices (PGP) Scale (8 items), the Health Behaviour Scale (5 items), and the Infertility Stigma Scale (5 items). Responses indicated strong agreement that cost and lack of facilities act as barriers (M = 4.2, SD = 0.7 and M = 4.3, SD = 0.6 respectively), alongside insufficient awareness campaigns (M = 4.1, SD = 0.8). However, participants rated pharmacist counselling (M = 3.2, SD = 0.9) and communication between pharmacists and gynaecologists (M = 3.0, SD = 1.0) less positively.

These findings reflect participants' perceptions of healthcare practices and system-level barriers rather than direct assessment of professional performance or institutional data. On health behaviours, participants moderately agreed with maintaining a healthy diet (M = 3.7, SD = 0.8) and regular physical activity (M = 3.5, SD = 0.9), but higher endorsement was seen for following medical advice on supplementation (M = 4.1, SD = 0.7). Infertility stigma received particularly high scores for self-confidence impact (M = 4.2, SD = 0.6) and social judgement (M = 4.3, SD = 0.7), with strong agreement across family and marital tension items, highlighting the cultural salience of infertility in the Libyan context. These stigma-related findings are based on self-reported experiences and should be interpreted as subjective psychosocial perceptions rather than clinically validated psychological outcomes.

Table 4. Pharmacy–Gynaecology Practices, Health Behaviour, and Infertility Stigma (n = 1,000 participants)

Scale	Item No.	Statement	Mean ± SD
PGP	1	Pharmacists provide adequate counselling about vitamin D supplementation.	3.2 ± 0.9
	2	Gynaecologists routinely request vitamin D testing in infertility assessments.	3.4 ± 0.8
	3	There is effective communication between pharmacists and gynaecologists in patient care.	3.0 ± 1.0
	4	Cost of vitamin D supplements limits access for many women.	4.2 ± 0.7
	5	Lack of laboratory testing facilities hinders accurate diagnosis of vitamin D deficiency.	4.3 ± 0.6
	6	Awareness campaigns about vitamin D and reproductive health are insufficient.	4.1 ± 0.8
	7	Patients rely more on pharmacy advice than gynaecological consultation for supplements.	3.6 ± 0.8
	8	A coordinated guideline is needed for managing infertility linked to vitamin D deficiency.	4.4 ± 0.5
Health Behaviour	1	I maintain a healthy diet.	3.7 ± 0.8
	2	I engage in regular physical activity.	3.5 ± 0.9
	3	I limit consumption of processed foods.	3.6 ± 0.7
	4	I undergo regular health check-ups.	3.8 ± 0.8
	5	I follow medical advice regarding supplementation.	4.1 ± 0.7
Infertility Stigma	1	Infertility affects my self-confidence.	4.2 ± 0.6
	2	Infertility causes tension in family relationships.	4.0 ± 0.8
	3	Society judges women for not conceiving.	4.3 ± 0.7
	4	Infertility affects marital stability.	4.1 ± 0.7
	5	I feel pressure from relatives or community about having children.	4.2 ± 0.6

3.4 Hypotheses Testing Results

The final stage of statistical analysis examined three hypotheses regarding the association between vitamin D awareness, perceived deficiency-related risk, and infertility experiences, alongside the perceived practices of pharmacists and gynaecologists in Derna and Tobruk. Prior to hypothesis testing, the dataset was screened for normality using the Shapiro–Wilk and Kolmogorov–Smirnov tests, with histograms and Q–Q plots confirming that continuous variables followed a near-normal distribution. This justified the use of parametric tests, specifically Pearson's correlation, independent samples t-tests, and multiple regression. Statistical significance was set at $p < 0.05$, with 95% confidence intervals (CIs) reported to assess the strength of associations. Reliability analysis confirmed strong internal consistency for all scales (Cronbach's $\alpha > 0.80$).

Hypothesis 1 proposed that vitamin D deficiency would be significantly associated with infertility experiences. Pearson's correlation analysis supported this hypothesis, showing a positive correlation between Vitamin D Awareness and Deficiency (VDAD) scores and Infertility Experiences and Perceptions (IEP) scores ($r = 0.42$, $p < 0.001$). Logistic regression further confirmed that participants with lower VDAD scores were more likely to report infertility experiences (OR = 1.53, 95% CI [1.22, 1.91], $p < 0.001$). It is important to clarify that the VDAD scale represents awareness and perceived deficiency-related factors rather than biochemical vitamin D levels, and therefore the observed relationship reflects an association between perception-based variables rather than a direct physiological link.

Hypothesis 2 examined differences in knowledge and practices between pharmacists and gynaecologists. Independent samples t-tests demonstrated a significant mean difference on the Pharmacy–Gynaecology Practices (PGP) scale ($t = 4.26$, $df = 998$, $p < 0.001$). Pharmacists reported greater involvement in supplement provision, while gynaecologists reported stronger reliance on clinical testing and diagnostic protocols. However, these findings are derived from participants' perceptions of professional roles rather than direct data collected from pharmacists or gynaecologists, and should therefore be interpreted as perceived differences rather than actual professional comparisons.

Hypothesis 3 assessed whether systemic barriers in pharmacy and gynaecology practices predicted infertility experiences. Multiple regression analysis revealed that cost of supplements, lack of laboratory testing, and insufficient inter-professional communication significantly predicted IEP scores ($\beta = 0.31$, $p < 0.001$; $\beta = 0.28$, $p = 0.002$; $\beta = 0.25$, $p = 0.004$, respectively). Collectively, the model explained 36% of the variance in infertility experiences ($R^2 = 0.36$, $F(3, 996) = 72.41$, $p < 0.001$), supporting the hypothesis that systemic factors exert a measurable influence on reproductive health outcomes. These findings indicate associative relationships within a cross-sectional framework and do not imply causality between healthcare system factors and infertility outcomes.

Table 7. Summary of Hypothesis Testing Results (n = 1,000)

Hypothesis	Statistical Test Used	Result	Significance	Interpretation
H1: Vitamin D awareness, perceived deficiency-related risk, and supplementation practices are associated with infertility experiences	Pearson's correlation + Logistic Regression	r = 0.42; OR = 1.53 (95% CI [1.22, 1.91])	$p < 0.001$	Supported
H2: Perceived differences in pharmacy and gynaecology roles influence reported practices	Independent t-test	t = 4.26, df = 998	$p < 0.001$	Supported
H3: Systemic barriers in pharmacy–gynaecology practices predict infertility experiences	Multiple Regression	$\beta = 0.31$; $\beta = 0.28$; $\beta = 0.25$; $R^2 = 0.36$	$p < 0.001$	Supported

4. Discussion

The key finding indicating that vitamin D awareness was relatively high while supplementation practices remained limited demonstrates an important gap between knowledge and behaviour. Participants largely agreed that vitamin D contributes to reproductive health and that deficiency increases infertility risk, which aligns with mechanistic reviews linking deficiency to ovulatory dysfunction and impaired implantation [1]. However, reported supplementation and reliance on dietary sources were relatively low, echoing findings from international reviews where awareness did not consistently translate into action due to affordability or accessibility constraints [15]. Similar inconsistencies have been documented in the NHANES-based analysis, where serum deficiency was common even though participants were aware of dietary and environmental determinants [2]. It should be noted, however, that the present study assessed awareness and self-reported practices rather than biochemical vitamin D status, and therefore the findings reflect perceived deficiency-related risk rather than confirmed physiological deficiency. The discrepancy between awareness and action in Derna and Tobruk probably reflects structural limitations in health service provision, such as limited access to laboratory testing and inconsistent supplementation guidance. The implication of this pattern is that interventions in Libya may need to prioritise not only health education but also practical pathways for supplement provision and monitoring.

The results show that infertility was experienced as both a personal health concern and a socially stigmatised condition, consistent with broader literature documenting the psychological and cultural weight of infertility. High agreement with items relating to emotional distress and social stigma aligns with previous observations that infertility carries significant psychological burden and community judgement [16]. Evidence suggests that stigma may exacerbate distress and deter women from seeking biomedical treatments such as assisted reproductive technologies [21]. The relatively low uptake of ARTs and laboratory testing in the current sample is comparable to findings in North African and Middle Eastern contexts where access barriers, cost, and cultural reservations limit utilisation [15]. Such underuse of diagnostic and treatment options probably reflects both economic and normative influences, as women may anticipate

criticism or limited support from family networks. In addition, infertility in this study was measured as a self-reported experience rather than a clinically confirmed diagnosis, which may have introduced recall bias and potential misclassification of fertility status. The implication here is that infertility-related services in Libya should be expanded alongside stigma reduction strategies to foster earlier help-seeking.

The study finding that vitamin D deficiency was significantly associated with infertility experiences illustrates the importance of nutritional determinants of reproductive health. The positive correlation between deficiency awareness and infertility experiences mirrors evidence from cohort studies that linked low serum vitamin D with higher rates of anovulation and reduced live birth among women with PCOS [7]. Moreover, Zhao, Fu and Chen [2] demonstrated that low vitamin D levels were closely tied to obesity-related infertility, raising the possibility that metabolic pathways mediate the association. While causality cannot be inferred from cross-sectional data, the observed relationship is consistent with biological plausibility established in mechanistic research [4,5].

However, this association should be interpreted cautiously, as the VDAD scale represents awareness and perceptions rather than direct measurement of serum vitamin D levels, and therefore does not establish a biological deficiency–infertility relationship. These patterns probably suggest that screening for deficiency could be integrated into reproductive health assessments to identify at-risk groups more effectively. The implication is that health services in Derna and Tobruk should incorporate vitamin D testing within infertility evaluations, with supplementation considered as a routine adjunct to care.

The study results further demonstrate that systemic barriers in pharmacy and gynaecology practices significantly predicted infertility experiences, highlighting a service delivery challenge. Distinct roles were reported, with pharmacists more engaged in supplement provision and gynaecologists more reliant on diagnostic testing, echoing previous observations that fragmented care undermines effective management [15]. The regression findings showing cost, testing availability, and inter-professional communication as predictors of infertility perceptions resonate with earlier analyses where health system constraints shaped reproductive outcomes as strongly as individual-level factors [9]. Weak coordination between professional groups may limit consistent counselling and follow-up, resulting in missed opportunities for prevention.

It is important to clarify that these findings are based on participants' perceptions of pharmacy and gynaecology practices rather than direct data collected from healthcare professionals, and therefore reflect perceived rather than objectively measured differences between professional roles. It is probable that the absence of coordinated guidelines in Libya reinforces these gaps, as similar contexts without structured supplementation protocols have shown inconsistent outcomes [13]. The implication is that collaborative frameworks between pharmacists and gynaecologists are urgently required to strengthen continuity of care for women with infertility linked to vitamin D-related factors.

4.1. Theoretical and Practical Implications

The present findings contribute to theoretical perspectives on nutritional determinants of reproductive health by situating vitamin D deficiency within biomedical, professional, and systemic contexts. However, the study operationalises vitamin D deficiency through awareness,

perceptions, and supplementation practices rather than direct biochemical measurement, and therefore reflects perceived deficiency-related risk rather than confirmed physiological deficiency. Unlike models focusing solely on physiological deficiency, this study illustrates that awareness, clinical engagement, and healthcare system barriers interact in shaping infertility experiences. The observed association between lower vitamin D scores and higher infertility experiences supports mechanistic reviews highlighting the role of vitamin D in ovulatory dysfunction and implantation [1]. The significant divergence in practices between pharmacists and gynaecologists resonates with service delivery models that emphasise professional complementarity yet reveal gaps in coordination [15]. Furthermore, the predictive influence of systemic barriers such as testing availability and inter-professional communication echoes findings from international cross-sectional studies that identified structural determinants of infertility management [2]. These insights should be interpreted within the limits of a cross-sectional design, which identifies associations rather than causal pathways between variables. These insights extend theoretical models by demonstrating how biomedical risk factors are mediated through healthcare organisation and professional roles.

Practically, reproductive health services in Libya must address both clinical and structural barriers. Pharmacists were shown to play a major role in supplement provision, while gynaecologists relied more heavily on diagnostic protocols, underscoring the importance of coordinated care. Importantly, these findings are based on participants' perceptions of professional practices rather than direct data collected from pharmacists and gynaecologists, and therefore represent perceived differences rather than objective professional comparisons. The absence of consistent supplementation and testing guidelines probably constrains effective management, as seen in other MENA contexts where supplementation is inconsistently prescribed [13, 14]. A practical application of these findings is the integration of unified clinical guidelines for vitamin D testing and supplementation into infertility care, with coordinated responsibilities between pharmacists and gynaecologists. Such integration would ensure that awareness of deficiency translates into action and patient-centred management.

5. Strengths and Limitations

One strength of the study lies in its large sample size (n = 1,000), equally drawn from Derna and Tobruk, which enabled comparative analysis across two demographically distinct urban centres in Libya. The development of a structured questionnaire, informed by validated scales from prior international studies [1,2], contributed to strong internal consistency across measures of vitamin D awareness, infertility experiences, and professional practices (Cronbach's $\alpha > 0.80$). The study's focus on perceptions, behaviours, and system-level factors provides a broader contextual understanding of infertility beyond purely biomedical indicators. The inclusion of both patients and healthcare professionals expanded the analysis beyond individual perceptions to encompass systemic influences, offering a multi-dimensional understanding of infertility risk and management. The combination of hypothesis-driven statistical modelling with descriptive analysis ensured both rigour and relevance for public health application.

Nevertheless, several limitations require acknowledgement. The reliance on self-reported infertility experiences, rather than confirmed clinical diagnoses, introduces potential recall and reporting bias. Infertility in this study was defined based on self-reported difficulty conceiving for one year, without clinical confirmation, partner evaluation, or hormonal assessment, which

may result in misclassification. Vitamin D status was assessed through perceptions and practices rather than direct biochemical measurement, limiting comparability with studies employing serum markers [2]. The absence of serum 25(OH)D measurement represents a key methodological limitation, restricting the ability to draw conclusions about actual vitamin D deficiency prevalence. The cross-sectional design prevents causal inference, meaning the directionality between deficiency and infertility cannot be established. Furthermore, the sample was urban-based, potentially under-representing rural populations where deficiency and infertility may be more pronounced due to socioeconomic and service access disparities. Finally, the study did not incorporate qualitative methods to capture the cultural and social meanings surrounding vitamin D supplementation and infertility stigma, which could have enriched interpretation.

6. Recommendations for Future Research

Future research should prioritise longitudinal designs to clarify the causal relationship between vitamin D deficiency and infertility, including whether supplementation can reduce infertility rates over time. Incorporating biochemical measures of serum 25(OH)D would allow validation of self-reported perceptions and provide clinically robust evidence comparable to international studies. Expanding the sample to rural and peri-urban populations in Libya could reveal geographic disparities in supplementation practices, healthcare access, and stigma, which remain unexplored. Mixed-methods approaches, particularly qualitative interviews with women, pharmacists, and gynaecologists, may provide deeper insights into why awareness of deficiency does not consistently lead to supplementation, and how stigma interacts with health-seeking behaviour.

Further research could also assess intervention strategies, such as integrating vitamin D testing into routine reproductive care, subsidising supplementation for low-income households, and developing inter-professional training modules to strengthen collaboration between pharmacists and gynaecologists. Large-scale randomised controlled trials in North Africa, similar to those conducted in Europe and Asia [15], would offer more conclusive evidence regarding supplementation protocols. By addressing both biomedical and structural determinants, future research may inform reproductive health policies that are better aligned with Libyan healthcare realities.

7. Conclusion

The study has demonstrated that perceived vitamin D deficiency–related factors are associated with self-reported infertility experiences in Derna and Tobruk and that professional practices and systemic barriers substantially shape this relationship. These findings should be interpreted as associations rather than evidence of causality or confirmed biochemical deficiency. While participants displayed relatively high awareness of vitamin D's role in reproductive health, gaps persisted in supplementation practices and testing uptake, highlighting structural obstacles to effective management. Pharmacists and gynaecologists reported distinct but complementary roles, yet weak coordination and lack of unified guidelines limited consistent care. These findings reinforce the importance of addressing both clinical and system-level determinants of infertility. Improving supplementation protocols, strengthening inter-professional communication, and embedding vitamin D screening into reproductive health pathways could contribute to more effective, culturally sensitive infertility care in Libya.

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