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Vitamin D Deficiency in Elderly Postmenopausal Women: The Role of Sunlight, Diet, and Vitamin D Status

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Abstract

In Indonesia, the prevalence of vitamin D deficiency in Indonesia was quite high, reaching 35.1–91.7% in the elderly, especially women. Vitamin D is crucial for postmenopausal (elderly) women to maintain bone density, prevent osteoporosis, and reduce the risk of falls due to muscle weakness. The study objective was to determine the influence of sunlight, dietary supplement intake, and physical activity on the risk of Vitamin D deficiency in elderly postmenopausal women. This study used a cross-sectional design and was conducted from October to November 2024 at a nursing home in Surabaya. The respondents were elderly postmenopausal women (>60 years) who lived in a nursing home in Surabaya, with no comorbidities that affect the ability to eat and do physical activities. The sampling technique in the study was purposive sampling. Their correlations were determined using the Spearman correlation test to identify the correlation between sun exposure, diet, and vitamin D status with vitamin D level. The average age of respondents was 63.47±73.25 years in 57 respondents. The average vitamin D level was 19.4667±6.67 ng/mL. Higher sun exposure leads to higher blood vitamin D levels. For dietary, indicating a significant relationship between higher egg and/or vitamin D supplement intake and increased blood vitamin D levels. Most respondents had a high risk of vitamin D deficiency, and vitamin D level insufficiency was 29 people (50.88%). There was a significant relationship between sun exposure frequency, egg diet, vitamin D supplements, vitamin D status variables, and vitamin D levels.

Introduction

Vitamin D deficiency affects almost half of the world's population. It is estimated that almost all ethnicities and age groups experience vitamin D deficiency. Vitamin D plays an important role in human health because it can reduce the risk of various diseases such as cancer and autoimmune diseases, multiple sclerosis, arthritis, and diabetes (Rebelos *et al*., 2023; Fenercioglu, 2024). Various factors are thought to be the cause of vitamin D deficiency, such as lifestyle and environmental conditions (Lorensia *et al*., 2025; Santana *et al*., 2022).

In tropical countries in Asia, such as Indonesia. Although Indonesia is located on the equator with year-round sunlight exposure, lifestyle changes and air pollution increase the risk of vitamin D deficiency and its skeletal consequences. The Southeast Asian Nutrition Surveys (SEANUTS) study showed that only 5.6% of respondents in Indonesia had the desired vitamin D levels (Pulungan *et al*., 2021). Vitamin D deficiency is common in geriatrics, especially in individuals with comorbidities and polypharmacotherapy. In this group, low plasma vitamin D concentrations are associated with osteoporosis, osteomalacia, sarcopenia, and myalgia. Vitamin D levels in humans are

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the result of joint interactions of all vitamin D metabolic pathways (Kupisz-Urbańska *et al*., 2021). In Indonesia, the prevalence of vitamin D deficiency, especially in the geriatric female population, is very high. Vitamin D deficiency in elderly women can be triggered by inadequate dietary intake, sun exposure, and metabolic diseases, which then result in incomplete osteoid mineralization in cortical and cancellous bones and cause bone disorders (Giustina *et al*., 2023; Lorensia *et al*., 2024a). Menopause is a natural phase experienced by every woman caused by a decrease in estrogen hormones from the ovaries. This condition can affect physical and mental health and contribute to changes in quality of life and increased health risks for women (Smith *et al*., 2017). In women, vitamin D plays an important role in supporting the function of the estrogen hormone in every phase of life, in addition to its ability to increase the absorption of calcium and phosphorus in the intestine to maintain bone and tooth density (Mei *et al*., 2023). Entering menopause, estrogen levels decrease significantly, so that vitamin D levels also decrease, which causes a decrease in the body's ability to absorb calcium and increases the risk of osteoporosis (Mei *et al*., 2023; Cheng *et al*., 2022). Therefore, vitamin D is very much needed by women aged ≥65 years, with an adequacy rate of at least 150µg (600 IU) (Pliz *et al*., 2019).

Vitamin D deficiency in elderly menopausal women in Indonesia is largely influenced by a combination of decreased skin synthesis, reduced direct sunlight exposure due to closed clothing/lifestyle choices, and hormonal factors. With aging, the skin's ability to produce vitamin D decreases, and the synthesis of vitamin D precursors decreases. Furthermore, many elderly women spend more time indoors, wear closed clothing (long sleeves/long skirts), or avoid the sun (Alyahya, 2020; Zareef *et al*., 2018). In addition to sun exposure, intake of foods high in vitamin D (such as milk, fish, and eggs) and supplements contributed most to vitamin D intake. The prevalence of osteopenia was 33% in the lumbar spine and 30% in the femoral neck. There was a significant positive association between calcium intake and bone mineral density at the lumbar spine (Zareef *et al*., 2018). There is strong evidence that physical activity early in life contributes to higher peak bone mass. Some evidence indicates that resistance and high-impact exercise are likely the most beneficial (Narula *et al*., 2013).

The Endocrine Society classifies 25[OH]D levels into three categories: sufficiency (30-100 ng/mL), insufficiency (21-29 ng/mL), and deficiency (<20 ng/mL) (Szpunar, 2020). Vitamin D deficiency can be diagnosed by measuring serum 25(OH)D. Vitamin D levels, meanwhile, are tested using the Human Vitamin D Enzyme-Linked Fluorescence Assay (ELFA), an objective laboratory technique to determine serum 25[OH]D concentrations, which are the primary biological indicator of vitamin D status in the body. Although serum levels are more accurate, questionnaires are still useful to provide context for behaviors that may affect vitamin D status (Pliz *et al*., 2019), namely through the vitamin D status questionnaire. Vitamin D status consists of 15 questions divided into 4 categories: duration of sun exposure, consumption of foods containing vitamin D, consumption of fish oil and supplements, and signs and symptoms of vitamin D deficiency (Pliz *et al*., 2019). The questionnaire was used to identify factors contributing to vitamin D status, such as duration of sun exposure, diet, and lifestyle. This method is subjective because the results given depend on self-reported responses (Pliz *et al*., 2019). Vitamin D status in the community is influenced by the production of vitamin D3 due to sun exposure, food intake, or supplements. Most of the body's vitamin D sources are obtained through skin exposed to sunlight, while the rest comes from food intake (Santana *et al*., 2022; Pliz *et al*., 2019). Vitamin D status questionnaire has been widely used in Indonesia to describe vitamin D conditions with vitamin D status. Previous research in Surabaya in adult society showed that all respondents had vitamin D levels below normal. Therefore, behavioral changes are needed through improving lifestyle, diet, and physical activity in the community (Lorensia *et al*., 2022). The combination of the two approaches is expected to provide a more comprehensive picture of vitamin D status in the geriatric female population. Given the prevalence of quite high vitamin D deficiency in the geriatric female population, this study is important to understand the factors that affect vitamin D levels, especially in the geriatric group (Pliz *et al*., 2019). Previous research on the vitamin D status of 450 physically active elderly who did not use vitamin D supplements determined information on possible determinants (demographics, dietary intake, and physical activity). In physically active elderly, vitamin D status was very high in summer, with little deficiency, suggesting that elderly with a physically active lifestyle may not need supplements during the summer period. Lower age, lower BMI, higher alcohol intake, and more outdoor physical activity were significantly associated with vitamin D status (Lorensia *et al*., 2024b). The study objective was to determine the influence of sunlight, dietary supplement intake, and physical activity on the risk of Vitamin D deficiency in elderly postmenopausal women.

Method

This study used a cross-sectional design to assess the relationship between vitamin D status and vitamin D levels. The research variables included vitamin D status and vitamin D levels in the blood. This study will be conducted from October to November 2024 at a nursing home in Surabaya. The vitamin D status questionnaire in this study consists of 15 items divided into 4 categories, namely duration of sun exposure, consumption of foods containing vitamin D, consumption of fish oil and supplements, and signs and symptoms of vitamin D deficiency (Santana *et al*., 2022; Lorensia *et al*., 2024; Pliz *et al*., 2019; Lorensia *et al*., 2024). Vitamin D levels are operationalized as the level of calcidiol 25[OH]D in the blood. Measurement of vitamin D levels in the body is done using a 25-dihydroxy vitamin D 25[OH]D blood test with the Enzyme-Linked Fluorescent Assay (ELFA) method with the help of a mini VIDAS device. Vitamin D levels are grouped into 3 groups, namely normal (30-100 ng/mL), insufficiency (20-29 ng/mL), and deficiency (<20 ng/mL) (Ten-Haaf *et al*., 2019; Amrein *et al*., 2020).

The population in this study was elderly postmenopausal women (>60 years) who live in a nursing home in Surabaya. The population size for elderly postmenopausal women was 60 people. The research subjects were part of the population who were willing to be involved in the research and met the criteria: (1) Able to communicate independently in interviews, (2) no comorbidities that affect the ability to eat and do physical activities. The sampling technique in the study was purposive sampling. This research questionnaire uses a questionnaire used to measure vitamin D status adapted from published research (Lorensia *et al*., 2024a; Pliz *et al*., 2019) which has been validated and is reliable for all questions from four categories. Vitamin D status data collection using a questionnaire and the questionnaire filling process is carried out by the respondents themselves.

Vitamin D (25(OH)D) levels are measurements of vitamin D levels by taking blood samples from respondents. The method of observing vitamin D (25(OH)D) levels used is the ELFA method (Enzyme-Linked Fluorescent Assay) with the Vidas tool from bioMerieux. The type of specimen that can be used in testing can be serum or blood plasma, with the procedure of taking 3cc of venous blood samples from the elbow crease by laboratory personnel. Before analysis, the blood sample is allowed to coagulate and then centrifuged to remove fibrin. The level testing is carried out by a certified Laboratory in Surabaya. Their correlations were determined using the Spearman correlation test. Statistical analysis was performed utilizing SPSS for Windows version 23, divided into two phases. First, descriptive analyses were done to describe the characteristics of the subjects. Categorical data were presented in frequency with percentage, and numerical data were presented in the median, minimum, and maximum values because of abnormal data distribution. Then, analysis continued using the Spearman correlation test to identify the correlation between sun exposure, diet, and vitamin D status with vitamin D level.

Result and Discussion

The respondents used in this study were elderly women living in a nursing home in Surabaya, with a total population of 60 people. However, only 57 respondents were able to fill out the questionnaire, considering that 3 other elderly women had health problems (were sick or had a history of dementia), so they could not participate in filling out the questionnaire. The average age of respondents was 63.47±73.25 years (Table 1).

Body Mass Index (BMI) is an important indicator to assess the nutritional status and health of elderly women (age >60 years). BMI has a close relationship with various aspects of health, especially related to the risk of chronic diseases, quality of life, and mortality in this age group (Giustina *et al*., 2024). BMI has a significant impact on vitamin D status in elderly women over 60 years of age. This relationship is influenced by physiological, metabolic, and lifestyle factors that are typical of this age group. Elderly women with low BMI (<18.5) are at risk of vitamin D deficiency due to low dietary intake and lack of body fat reserves, thus having a high tendency to experience osteoporosis, muscle weakness, increased risk of falls (Sweatt *et al*., 2024). Most respondents were classified as having a normal BMI (49.12%) and thin (31.58%) (Table 1).

Table 1. Respondent Characteristics

		Frequency (n=57)	Percentage (%)
Body Mass Index (kg/m^2)	Thin (<18.5)	18	31.58
	Normal (18.5-24.9)	28	49.12
	Overweight (25-29.9)	10	17.55
	Obesity (≥ 30)	1	1.75
Medical History	None	18	36.84
	Osteoarthritis	8	14.04
	Parkinson's, stroke	10	17.54
	Coronary heart disease	13	22.81
	Osteoporosis	2	3.51
	Diabetes mellitus type 2	3	5.26

(Primary data, 2024)

Low BMI in elderly women is often associated with malnutrition and lack of vitamin D intake through food. This will have an impact on vitamin D status, risk of vitamin D deficiency due to lack of body fat reserves that can store vitamin D, and the possibility of consuming low-nutrient foods, such as sources of vitamin D, such as fatty fish, fortified milk, and egg yolks (Lech *et al*., 2024). Elderly women with low BMI are also at higher risk of experiencing decreased muscle and bone mass (osteomalacia or osteoporosis) due to vitamin D deficiency. Therefore, consuming foods rich in vitamin D and sufficient exposure to sunlight are very necessary (Ito *et al*., 2022).

Vitamin D has several links to diseases, such as bone disease and osteoporosis, type-2 diabetes, cardiovascular disease, autoimmune diseases, gastrointestinal disorders, kidney disease, as well as depression and cognitive disorders (Laksono *et al*., 2025). In general, three main factors influence the emergence of these diseases, including chronic diseases often limit outdoor activities, thereby reducing exposure to sunlight, polypharmacy occurs because some drugs, such as anticonvulsants and glucocorticoids, can interfere with vitamin D metabolism. Including age and the aging process, where old age reduces the efficiency of the skin in producing vitamin D from UVB rays (Giustina *et al*., 2023). Vitamin D deficiency can increase the renin-angiotensin-aldosterone system (RAAS), which can lead to hypertension. Another study also stated that systolic and diastolic blood pressure decreased with vitamin D administration in adults with high blood pressure. In addition, vitamin D deficiency is also associated with an increased risk of rheumatoid arthritis, considering that vitamin D has immunomodulatory properties that work on the immune system both endocrinologically and paracrinely (Jia *et al*., 2022). The instrument to measure vitamin D in this study used a questionnaire consisting

Table 2. Profile of Vitamin D Status

Domain	Question	Item	Frequency (n=57)	
Long Exposure to Sunlight	How many usually you get sun exposure in a way direct?	07.00-09.00	57	100.0
	Do you use skin protection (umbrella, hat, jacket, sunscreen, etc.) from direct sun exposure?	No	17	29.82
		Yes	40	70.18
	What skin protection tools do you use? **(There can be more than one answer)**	There isn't any	17	29.82
		Umbrella	4	7.02
		Hat	14	24.56
		Other	22	38.60
	How often do you use skin protection?	Never	17	29.82
		Every day	14	24.56
		Sometimes	18	31.58
		Seldom	8	14.04
	Do you usually wear close clothing such as long-sleeved shirts and long pants every day?	No	17	29.82
		Yes	40	70.18
	Which parts of your body would you like to protect from direct sun exposure with protective equipment? **(There can be more than one answer)**	Never	17	29.82
		Face	21	36.84
		Hand	12	21.05
		Back and Shoulders	2	3.51
		All over body	5	8.77
	Do you use cosmetic products (facial moisturizer, hand and body cream, powder, etc.) with SPF content?	No	32	56.14
		Yes	5	8.77
		Don't know	20	35.09
	Do the cosmetics you use contain protection from UVA and UVB?	No	37	64.91
		Yes	3	5.26
		Don't know	17	29.82

	Fish			
	Have you consumed fish in the past week?	No	5	8.77
		Yes	52	91.23
	What is your purpose in consuming fish?	It feels like	30	52.63
		Get benefit for Health	16	28.07
		It just so happened that fish dishes were available to eat	11	19.30
	Milk			
	Have you consumed milk in the last week?	No	18	31.58
		Yes	39	68.42
	Egg			
	Have you consumed eggs in the last week?	No	25	43.86
		Yes	32	56.14
	Do you take fish oil?	No	26	45.61
		Yes	31	54.39
	Do you take any supplements?	No	36	63.16
		Yes	21	36.84
Signs and symptoms of Vitamin D Deficiency	Have you ever experienced this condition?	Never	1	1.75
		Muscle pain including lower back pain	20	35.09
		Pain in the pelvis, back, and legs	5	8.77
		Muscle weakness	10	17.54
		Prone to bad moods or depression	1	1.75
		Low immunity such as frequent colds in winter	20	35.09

(Primary data, 2024)

of 15 questions categorized into 4 categories, namely the length of exposure to sunlight, consumption of foods containing vitamin D, consumption of fish oil and supplements, and signs and symptoms of vitamin D deficiency. The description of each question can be seen in Table 2.

Elderly women often experience vitamin D deficiency because the skin's ability to produce vitamin D decreases with age. However, Indonesia's nature as a tropical country means that elderly women are naturally exposed to the sun all year round, providing a source of vitamin D for elderly women. The required exposure to ultraviolet B (UVB) radiation has a wavelength of between 290-315 nm, which generally occurs until 09.00 (Pirrotta *et al.*, 2023). This was in accordance with the findings of this study, where all respondents (100%) received direct exposure to sunlight at 07.00-09.00 WIB (Table 2). According to Okan *et al.* (2022), the maximum vitamin D production that can be achieved after 10–15 minutes of morning sun exposure, especially during summer, is equivalent to an intake of more than 500 µg of Vitamin D3. In a common case found among elderly women, aging is significantly associated with a decrease in the concentration of 7-dehydrocholesterol, the precursor of vitamin D3 in the skin. In this case, women aged >60 years have about 25% less 7-dehydrocholesterol compared to young adults, thus having a 75% decrease in the capacity to make vitamin D3 in the skin. Thus, reduced production of 1,25-dihydroxyvitamin D by the kidneys and reduced intake of fortified foods also cause great difficulty in the formation of Vitamin D for the bodies of elderly women (Madhivanan *et al*., 2020).

Older women tend to be less active outdoors to avoid health problems and physical limitations, so exposure to sunlight needed for vitamin D synthesis is reduced. Even many of them were found to be using excessive protection to avoid sunlight (Mavar *et al*., 2024). In this study, the majority of respondents (70.2%) used skin protection (eg.: umbrellas, hats, jackets, sunscreen, etc.) from direct sunlight exposure, used other protective equipment such as umbrellas and hats (26.3%), were accustomed to wearing closed clothing such as long-sleeved shirts and long pants every day (14%), and prioritized protection such as the face and hands. Some respondents (5.3%) also used cosmetics containing protection from UVA and UVB (Table 2). Decreased vitamin D synthesis in the skin is the most important factor contributing to vitamin D deficiency in elderly women. In the process, vitamin D is produced in the skin through the conversion of 7-dehydrocholesterol to vitamin D3 (cholecalciferol) when exposed to UV-B light. In elderly women, the level of 7-dehydrocholesterol in the skin decreases significantly, so the skin's ability to produce vitamin D also decreases (Giustina *et al*., 2023).

Fish have the highest vitamin D content compared to other vitamin D-containing foods such as egg yolks, cheese, and mushrooms. In addition to vitamin D, fish generally also contain long-chain n–3 polyunsaturated fatty acids, amino acids, iodine, and selenium. Short- to medium-term fish consumption has intervention effects on polyunsaturated fatty acids, blood lipids, vitamin B-12 and selenium status, insulin and leptin concentrations, eicosanoids and adhesion molecule concentrations, and heart rate variability (Syahrial *et al*., 2022). Therefore, adequate vitamin D for elderly women should also be supported by vitamin D intake from food. As the results of this study have shown, most respondents (91.2%) like to consume fish, either because they like the taste (52.6%), health reasons (28.1%), or because there is a fish dish available to eat (19.3%). In addition to fish, most respondents also like to consume eggs (56.1%) (Table 2). Apart from fish, although no significant differences were found in the vitamin D status of elderly women, egg consumption was also found to have an impact on increasing 25[OH]D levels (Mendivil, 2021).

Fish oil and vitamin D supplements have a very important role in supporting the health of elderly women, especially in addressing various problems that often occur in this group, such as decreased bone density, muscle function, and cardiovascular health (Puglisi & Fernandez, 2022). Fish oil rich in omega-3 fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), can also maintain heart and blood vessel health, be anti-inflammatory, improve brain function and prevent dementia, and maintain bone and eye health. On the other hand, vitamin D supplements are often recommended for older women because the body's ability to synthesize vitamin D from sunlight decreases with age (Bouillon *et al*., 2023; Banaszak *et al*., 2024; Abu-Jadayil *et al*., 2021). The results of this study found that 54.4% of respondents consumed vitamin D supplements (Table 2). This showed that there was a good diet from the management a nursing home in Surabaya to provide vitamin D needs for elderly women. As the results of the study by Abolfathi *et al*. (2021), had shown a significant influence of fish oil consumption patterns and vitamin D supplements had a significant influence on improving the quality of life of elderly women. Vitamin D levels are grouped into 3 groups, namely normal (30-100 ng/mL), insufficiency (20-29 ng/mL), and deficiency (<20 ng/mL) (Ten-Haaf *et al*., 2019; Amrein *et al*., 2020). Most respondents had vitamin D levels classified as insufficiency (52.63%), with an average of 22.70 ng/mL. The average vitamin D level was 19.4667±6.67 ng/mL. The highest vitamin D level was 39 ng/mL, with the lowest level being 8 ng/mL.

The time of day when blood samples are taken also affects the results of vitamin D levels.

Vitamin D levels change naturally throughout the day, tending to increase by up to 20% during the day compared to morning or evening, especially when taking supplements (Banaszak *et al.*, 2024). Vitamin D has an important role in the regulation of bone metabolism and the process of calcium homeostasis and also has an important role in the regulation of the immune system (Abu-Jadayil *et al.*, 2021). Vitamin D is the only vitamin that can be naturally produced by the body when exposed to the sun, so it can be said that sunlight is a source of vitamin D. Ultraviolet (UV) radiation from the sun will convert 7-dehydrocholesterol in the skin into previtamin D3. Previtamin D3 will be taken to the liver, and with the help of the 25-OHase enzyme, it will be converted into 25(OH)D (Abolfathi *et al.*, 2021). Age is an important parameter that can affect vitamin D requirements, especially for elderly women. Based on the Adequate Intake, the vitamin D requirement for pre-elderly women (45–59 years) is 10 mcg/day (400 IU/day). At this age, women are approaching or have entered menopause. Decreased estrogen levels can accelerate bone mass loss, so vitamin D intake is very important to support calcium absorption. Meanwhile, for elderly women (>60 years), the amount of vitamin D needed is around 15 mcg/day (600 IU/day). The increase in needs compared to pre-elderly age is caused by the body's reduced ability to produce vitamin D through the skin due to the aging process (Ramasamy, 2020).

Factors that affect a person's vitamin D levels were: (1) Age, the ability to produce vitamin D in the skin in response to UVB exposure also decreases, as does the ability of the kidneys to convert vitamin D to its active form (Rebelos *et al.*, 2023; Santana *et al.*, 2022; Ramasamy, 2020); (2) Recent illness or injury can result in lower vitamin D levels. In addition, digestive conditions such as irritable bowel disease, Crohn's disease, leaky gut, or celiac disease can limit the absorption of vitamin D in the intestine. However, none of the respondents in this study had comorbidities that could affect vitamin D levels (Rebelos *et al.*, 2023; Santana *et al.*, 2022); (3) Certain foods that have natural vitamin D (eg. fish, meat, and eggs) or are fortified with vitamin D (eg. milk and other dairy products, some orange juices and cereals) can affect vitamin D levels. Reducing the consumption of these foods if they are usually in your diet can lower vitamin D levels. In addition, some foods contain vitamin D2 (not D3) such as irradiated mushrooms and some fortified foods (eg. rice milk and soy milk), and although our bodies can use this form, it is not as effective as vitamin D3. Furthermore, the amount of vitamin D available in foods is quite small compared to what most people need to achieve blood levels of at least 40 ng/ml (e.g., salmon has ~450 IU/serving and fortified milk has ~120 IU/cup) (Syahrial *et al.*, 2022; Mendivil, 2021; Puglisi & Fernandez, 2022; Dominguez *et al.*, 2021); and (4) Inadequate skin exposure to sunlight (or indoor UVB light), excessive sunscreen use, or lack of sun exposure during the middle of the day (10 am–2 pm) will limit vitamin D production. In addition, the amount of melanin in the skin affects vitamin D production. A person with more melanin (darker skin) may need 30 minutes of sun exposure to achieve the same vitamin D production as a person with less melanin (lighter skin) would achieve in 10 minutes. While some people can achieve very high levels of vitamin D (~60 ng/ml or 150 nmol/L) through regular sun exposure alone, others cannot achieve these levels without vitamin D supplementation (Santana *et al.*, 2022; Ten-Haaf *et al.*, 2019; Amrein *et al.*, 2020; Ito *et al.*, 2022).

Based on Table 3, the correlation coefficient between sun exposure and vitamin D levels was shown by a correlation coefficient of 0.479, indicating a unidirectional relationship. The significance value, Sig. (2-tailed), was <0.01, indicating a significant relationship: higher sun exposure leads to higher blood vitamin D levels. The easiest way to obtain vitamin D is through direct sunlight. In tropical Asian countries, such as Indonesia, where sunlight is expected to be sufficient, vitamin D deficiency is estimated to be between 35 and 57% (Augustine *et al.*, 2021). In India, despite its proximity to the equator, vitamin D deficiency is common. This may be due to factors such as season, duration, exposure to sunlight, clothing, and skin pigmentation, which may contribute to vitamin D deficiency (Harinarayan *et al.*, 2013).

Table 3. Factors of Sun Exposure, Diet, and Physical Activity with Vitamin D Levels in Blood

		Vitamin D Level					
		Deficiency (n=23)	**Insufficiency (n=30)**	**Normal (n=4)**	**Total**	**Statistical test**	**P value**
Sun exposure	High	1 (1.75%)	11 (19.30%)	4 (7.02%)	16 (28.07%)	Spearman's rho	Value= 0.479** Sig. (2-tailed) =<0.001
	Moderate	9 (15.79%)	10 (17.54%)	0	19 (33.33%)		
	Low	13 (22.81%)	9 (15.79%)	0	22 (38.60%)		
Diet	Fish	20 (35.09%)	28 (49.12%)	4 (7.02%)	52 (91.23%)	**Spearman's rho**	Value= 0.136 Sig. (2-tailed) =0.314
	Milk	15 (26.32%)	20 (35.09%)	4 (7.02%)	39 (68.42%)		Value= 0.106 Sig. (2-tailed) =0.433
	Egg	0	28 (49.12%)	4 (7.02%)	32 (56.14%)		Value= 0.900** Sig. (2-tailed) =<0.001
	Vitamin D supplements	0	1 (1.75%)	4 (7.02%)	5 (8.77%)		Value= 0.490** Sig. (2-tailed) =<0.001
Total score (vitamin D	Had risk of vitamin D deficiency	22 (38.60%)	1 (1.75%)	0	23 (40.35%)	**Spearman's rho**	Value= 0.667** Sig. (2-tailed) = 0.000
	Didn't have low risk of vitamin D deficiency	1 (1.75%)	29 (50.88%)	4 (7.02%)	34 (59.65%)		

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
(Primary data, 2024)ss

Modernization has also brought about changes in lifestyle and diet, resulting in low levels of vitamin D. Furthermore, increased pollution prevents sunlight from reaching the earth, resulting in reduced skin exposure (Riiccio, 2024). Ultraviolet B (UVB) sunlight (wavelength 290-315 nm) hits the skin, penetrates the epidermis, and breaks the B ring in the cell membrane, converting it into previtamin D, converting 7-dehydrocholesterol to previtamin D3, which is then thermally isomerized to vitamin D3 (cholecalciferol). This vitamin D3 was then carried to the liver to be hydroxylated to 25-hydroxyvitamin D (25(OH)D), then to the kidneys to be converted to the active form of the hormone 1,25-dihydroxyvitamin D (1,25(OH)2D) (1,25(OH)2D) (Neville *et al.*, 2021; Uçar and Holick, 2025).

For dietary factors, the correlation coefficients were 0.136 (fish), 0.106 (milk), 0.900 (egg), and 0.490 (vitamin D supplements), indicating that only egg consumption and vitamin D supplements have a unidirectional relationship. Furthermore, the significance value, Sig. (2-tailed), was also <0.01, indicating a significant relationship between higher egg and/or vitamin D supplement intake and increased blood vitamin D levels (Table 3). Previous research by O'Connell *et al.* (2021), who studied older people in Southern Ireland, showed that

21.0% and 1.2% of the study population were at risk of malnutrition and malnourished. The most common insufficiencies reported were energy (54.9%), fiber (82.7%), calcium (58.6%), magnesium (62.3%), iron (54.9%), folate (66.0%), vitamin D (93.2%), and vitamin E (61.1%). Increasing age did not significantly influence nutrient intakes in males, while vitamin D intakes decreased with age in females, and the incidence of dietary folate insufficiency was higher in the oldest females.

The process of vitamin D from food involves absorption in the small intestine, transport by vitamin D-binding protein (DBP), and two stages of hydroxylation (liver and then kidney) to the active form 1,25-dihydroxyvitamin D, which regulates calcium in the body. Vitamin D2 (plant) and D3 (animal) were metabolized similarly, but D3 was generally more effective (Chun *et al*., 2019; Jones, 2022; Voiculescu *et al*., 2025). According to the USDA (United States Department of Agriculture) nutrition list, salmon, tuna, mackerel, catfish, and snapper contain vitamin D. Every 85 grams contains about 400 IU. Skipjack tuna is a member of the tuna family. In Indonesia, mackerel is available in canned sardines and mackerel. Fish is a source of vitamin D. The highest amount of vitamin D is found in fish liver, ranging from 2 mg/kg to 477 mg/kg, with a maximum of 1200 mg/kg, depending on the type of fish. Some types of fish that contain vitamin D include fatty fish such as fresh salmon (600-1000 IU of vitamin D3), sardines (300 IU of vitamin D3), tuna (230 IU of vitamin D3), mackerel (250 IU of vitamin D3), snapper (347 IU of vitamin D3), and catfish contain small amounts of vitamin D, which is about 3 IU of vitamin D3/100g (USDA) (Lu *et al*., 2007; USDA, 2018). The frequency of fish consumption can affect vitamin D status. The cooking process does not significantly affect the vitamin D content in food products, because vitamin D is heat-resistant, but some fish processing processes also affect the amount of vitamin D. The amount of vitamin D in fish does not change if the fish is grilled, but the frying process with cooking oil can reduce the amount of vitamin D in fish by 50% due to the nature of vitamin D which is fat-soluble (Sridonpai *et al*., 2022).

Vitamin D in eggs is found in the yolk, with 20 IU of vitamin D3 or D2 per yolk. Egg yolks are a good source of vitamin D, containing 279 IU per 67 grams. Eggs are a rich source of protein and vitamin D, and the antioxidants in eggs also help prevent aging because egg nutrients promote cell degeneration (Browning & Cowieson, 2014; Thamteerasathian *et al*., 2026). The process of preparing eggs has a significant impact on the amount of vitamin D contained in eggs. Based on research by Mattila *et al* in 1999, it was found that eggs boiled for 10 minutes had 1-6% lower levels of vitamin D3 compared to raw eggs, while according to USDA data from 2015, raw and boiled eggs had 41 IU/50 g of vitamin D3, while fried eggs had 40 IU/46 g of vitamin D3. In addition to fried and boiled eggs, many people in Indonesia also consume eggs processed with STMJ (milk, eggs (raw), honey, and ginger) (Clark *et al*., 2023). Fortification is the process of adding one or more specific micronutrients (vitamins and minerals) to foods or foodstuffs to improve the nutritional status of public health. To meet the body's vitamin D needs, it is recommended to consume fortified products at least twice a day. People with low milk consumption can experience vitamin D deficiency. Fortified milk should contain 400 IU of vitamin D per liter. Meanwhile, cow's milk only contains 40 IU of vitamin D per liter. Therefore, the best milk is milk with vitamin D fortification. In Indonesia, fortified milk is usually found in ready-to-drink liquid milk packages (Olson *et al*., 2021; Pellegrino *et al*., 2021; Wong *et al*., 2025).

Determination of the categorization of the respondents' total score (risk of vitamin D deficiency) was carried out by looking at the median cutoff point value of the respondent data, where the categorization was carried out by looking at the median of all data (median=12). The total question score was divided into 2 categories, namely having no risk of deficiency (total score <12) and having a risk of deficiency (total score ≥12). Respondents who did not have a risk of deficiency were 34 people (59.65%) (min=1; max=11; mean=8.98±2.32), and those who had a risk of deficiency were 23 people (40.40%) (min=12; max=17; mean=13.40±1.39) (Table 3). Most respondents didn't have a low risk of vitamin D deficiency, and vitamin D level insufficiency was 29 people (50.88%). Table 3 showed a correlation coefficient of 0.667, which means the level of strength of the relationship (correlation) between the vitamin D level variable and vitamin D status is significant at a significance level of 0.01. The correlation coefficient was positive (0.667), so the relationship between the two variables is in the same direction, meaning that the better the quality of vitamin D status, the higher the vitamin D level. Based on the output, the significance value, or Sig. (2-tailed) was 0.000, because the Sig. (2-tailed) value was 0.000 <0.05 or 0.01, it means that there was a significant relationship between the vitamin D status variable and vitamin D levels.

The results of this study are similar to previous research by Bolek-Berquist *et al.* (2009), who hypothesized that a simple questionnaire could identify young adults with a high and low likelihood of vitamin D deficiency. The questions assessed use of vitamin D-containing supplements, milk, and sun exposure in order to test this hypothesis. One hundred eighty-four adults (mean age 24 years, 53% women, 90% Caucasian) participated in the study. Nearly three in four adults (71%) had 25(OH) D levels <30 ng/mL, and 26% were vitamin D deficient. Another study that also looked at the effect of a vitamin D questionnaire on vitamin D levels by De-Giuseppe *et al.* (2022) showed an inadequate status of Vitamin D, according to the current Italian reference values. A significant difference (p<0.0001) in the EVIDENCE-Q score was found among the three classes of vitamin D status (severe deficiency, deficiency and adequate), with the mean score higher in severe deficiency and lower in the adequate one. EVIDENCE-Q can be a useful and easy screening tool for clinicians in their daily practice at a reasonable cost, to identify subjects potentially at risk of vitamin D deficiency and to avoid unwarranted supplementation and/or costly blood testing.

Conclusion

There was a very strong and unidirectional significant relationship between sun exposure frequency, egg diet, and vitamin D supplements and vitamin D status with vitamin D levels. This was in accordance with the findings of this study, where all respondents received direct exposure to sunlight at 07.00-09.00 WIB. In this study, the majority of respondents used skin protection (eg.: umbrellas, hats, jackets, sunscreen, etc.) from direct sunlight exposure. Some respondents also used cosmetics containing protection from UVA and UVB. Most respondents had a high risk of vitamin D deficiency and vitamin D level insufficiency. This research was funded by the Research Center and Community Engagement at the University of Surabaya in Indonesia. The authors declare no conflict of interest.

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