



Association between physical activity and vitamin D status: A cross-sectional study from the PERSIAN Guilan cohort study

Mohammadreza Javid^{1†}, Farahnaz Joukar^{1†}, Amirreza Emamhadi¹, Saman Maroufizadeh², Mohammadreza Naghipour¹, Fariborz Mansour-Ghanaei^{1*}

1. Gastrointestinal and Liver Diseases Research Center, Guilan University of Medical Sciences, Rasht, Iran
2. Department of Biostatistics, School of Health, Guilan University of Medical Sciences, Rasht, Iran

ABSTRACT

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A surprisingly high prevalence of vitamin D (vit D) deficiency has recently been reported worldwide. This study investigated the association between vit D status and physical activity in the Prospective Epidemiological Research Studies in IRAN (PERSIAN) cohort study, while also considering the influence of potential confounders. This cross-sectional study has been conducted on 9522 participants aged 35 to 70. The serum vit D concentrations were measured, and participants were divided into three tertiles of low, moderate, and high levels of physical activity according to the metabolic equivalent of task (MET). The cutoff level for vit D deficiency was considered ≤ 12 ng/ml. The association of vitamin D deficiency with physical activity (PA) was examined using logistic regression analysis. Odds ratio (OR)s were adjusted for vit D supplement use, sociodemographic characteristics, and additional covariates. About 4428 participants were male, and the mean age of participants was 51.46 ± 8.91 years. The prevalence of vit D deficiency was 22.8% and more common in women than men (23.8% vs. 21.7%). The prevalence of vit D deficiency decreased with increasing physical activity ($P < 0.001$). In the adjusted model for vit D supplements and sociodemographic characteristics, the participants with low physical activity had a higher risk of vit D deficiency than participants with high physical activity. According to our findings, vit D deficiency was associated with a reduced frequency of participation in all forms of physical activity.

*Corresponding Author(s):

Fariborz Mansour-Ghanaei, MD, AGAF

Address: Gastrointestinal and Liver Diseases Research Center, Razi Hospital, Sardar-Jangle Ave., P.O. Box: 41448-95655, Rasht, Iran

Tel: +98 13 15535116

E-mail: fmansourghanaei@gmail.com

† The authors contributed equally to this work.



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1. Introduction

Recently, vitamin D (vit D) deficiency has been recognized as a severe global problem [1,2]. It is estimated that over one billion people worldwide suffer from vit D deficiency [3]. In the USA, approximately 34–37% of adults have serum 25-hydroxyvitamin D [25(OH)D] levels below 20 ng/mL, while in Iran this figure reaches about 51%, with an even higher prevalence of severe deficiency among the elderly and those with comorbidities [4,5]. A meta-analysis study from Iran reported an overall prevalence of vit D deficiency of 56% in the general population [6].

Studies have demonstrated that vit D deficiency is associated with various chronic conditions, including hypertension, diabetes, and obesity, and may contribute to exercise intolerance and muscle weakness. Patients with diabetes are particularly vulnerable to severe comorbidities, such as infections, cardiovascular and renal diseases, dyslipidemia, and pulmonary complications, and are more likely to require intensive care under health critical situations [7–13]. Evidence suggests that vit D deficiency is linked to higher glycemic indices in individuals with diabetes and is associated with an increased risk of dyslipidemia, particularly among men [14,15].

The vit D status variation depends on various factors, including sun exposure, geographic region, skin color, genetics, weight, and diet [16,17]. Additionally, physical activity and sociodemographic factors may influence vitamin D status [18,19]. A previous study revealed that physical activity increases vit D, blood calcium, and bone mass and decreases calcium excretion [20]. In contrast, another study reported that less than 30 minutes of outdoor activity per day increases the risk of vit D deficiency by 1.32-fold [21]. Regularly engaging in physical activity has multiple benefits for humans but is affected by environmental, socioeconomic, physiological, and psychological factors that can be stimulating or inhibiting [22].

Sociodemographic factors such as age, sex, education, and lifestyle habits can influence both physical activity levels and vitamin D status. Large-scale research is warranted to confirm the association between physical activity and vit D status in individuals to facilitate proactive health management. Therefore, this study aimed to investigate the association between vit D status and physical activity and related sociodemographic factors using data from the Prospective Epidemiological Research Studies in Iran (PERSIAN) Guilan cohort study (PGCS), a large-scale domestic survey [23].

2. Materials and Methods

2.1 Participants and Study Design

This cross-sectional has been conducted on participants from the PGCS in Sowmeh' E Sara, Guilan, Iran, on 9522 individuals out of 10520 participants aged

35-70 years. Informed consent was obtained from all participants [24], and the study was confirmed by the ethical committee of the Guilan University of Medical Sciences [IR.GUMS.REC.1402.600]. The demographic data and clinical characteristics, including age, gender, marital status, education level, employment, habitat, history of hypertension and diabetes, smoking, hookah, opium, alcohol consumption, body mass index (BMI), wealth score index (WSI), serum 25-hydroxyvitamin D (25(OH)D) level, consuming vit D supplements, and physical activity according to the metabolic equivalent of task (MET) were surveyed. In addition, anthropometric indices containing weight (kg) and height (cm) were measured and, according to the BMI, divided into four groups as follows: underweight (BMI <18.5 kg/m²), average weight (BMI = 18.5–24.99 kg/m²), overweight (BMI = 25–29.9 kg/m²) and obese (BMI ≥30 kg/m²). WSI is an index used to evaluate socioeconomic status divided into three tertiles: low-income, middle-income, and high-income.

The MET was used to assess the physical activity intensity based on a standardized classification of the energy costs of different physical activities. MET was calculated using designed questionnaire to PERSIAN cohort study in Iran. The validity and reliability of this study has been investigated in the Iranian population [25]. The oxygen which is used during rest and immobility is equal to MET. Our population was divided into three tertiles according to low (<36.1), moderate (36.1-42.8), and high (>42.8) levels of physical activity according to daily activity levels by the number of hours of walking, working, exercise, etc. [26]. The types of activities and their associated MET values are assessed in the supplementary section [26]. Blood samples were taken from all participants, and the serum 25(OH)D was measured with Roche Elecsys 2010 and Cobas E411 auto analyzer (Roche Diagnostics GmbH, Mannheim, Germany) [27]. Different societies recommend the sufficiency level of serum vit D, but most examined the threshold for 25(OH)D. For example, the National Academy of Medicine recommends sufficient 25(OH)D >50 nmol/l (>20ng/ml), insufficient 25(OH)D 30-50 nmol/l (12-20 ng/ml), and low 25(OH)D <30 nmol/l (<12 ng/ml) [28], in which we consider <12ng/ml as the cutoff of for vit D deficiency. The accuracy and precision of all methods were performed according to the related guidelines.

2.2 Statistical analysis

The continuous variables were presented as mean ± standard deviation (SD) and categorical variables as number (percentage). Differences in continuous and categorical variables between participants with and without vit D deficiency were tested by independent t-test and Chi-square test (or Cochran–Armitage test for trend), respectively. We determined the association of vit D deficiency with physical activity using logistic regression analysis and calculated odds ratio (OR) with

95% confidence interval (CI). ORs were adjusted for using vit D supplement and sociodemographic characteristics; Model 1: unadjusted, Model 2: adjusted for vit D supplement use, Model 3: adjusted for hypertension and diabetes patients and Model 4: adjusted for vit D supplement use and sociodemographic characteristics (age, sex, marital status, years of education, occupation, place of residency, wealth score index, BMI, smoking, hookah smoking, opium consumption, alcohol consumption, hypertension and diabetes). All data analyses were performed using IBM SPSS Statistics for Windows, version 26.0, and a $P < 0.05$ was considered statistically significant.

3. Results

Table 1 describes the demographic and clinical characteristics of the participants. The mean age of the participants was 51.46 ± 8.91 years, and 53.5% were female. About 90.5% were married, 54.8% were employed, 54.3% were residents in rural areas, 32.6% were obese, 24.7% were smokers, 44.8% of participants had hypertension, and 24.8% had diabetes. Compared to participants without vit D deficiency, participants with vit D deficiency were at a younger age, female gender, single, unemployed, rural residents, had a high level of

education, high WSI, upper BMI, and low physical activity, and reported less alcohol consumption. The prevalence of vit D deficiency was 22.8% in this study and was more prevalent in females than in males (23.8% vs 21.7%). The prevalence of vit D deficiency was lower in older participants; the highest was 25.8% in those aged 35 to 44.

As presented in Table 2, the prevalence of vitamin D deficiency among participants with low, moderate and high physical activity was 25.2, 22.5, and 20.8%, respectively. In the other words, the prevalence of vitamin D deficiency decreased with increasing physical activity (P for trend < 0.001). According to the logistic regression analysis, in the unadjusted model, participants with low levels of physical activity had higher vit D deficiency than participants with a high level of physical activity (OR=1.28, 95% CI: 1.14–1.44). A similar result was obtained after adjustment for vit D supplement consumption (OR=1.30, 95% CI: 1.15–1.46) (Model 2) and adjusting for hypertension and diabetes patients (OR=1.30, 95% CI: 1.15–1.46) (Model 3). In model 4, after adjustment for vit D supplement consumption and sociodemographic characteristics, those with a low level of physical activity had higher odds of vit D deficiency (OR=1.15, 95% CI: 1.01–1.31) (Table 3).

Table 1. Demographic and clinical characteristics of participants in the PERSIAN Guilan cohort study (n=9522).

Variables	Total	Vitamin D Deficiency		P-value
		Yes (≤ 12 ng/mL)	No (> 12 ng/mL)	
Age (years)				<0.001
35-44	2866 (30.1)	739 (25.8)	2127 (74.2)	
45-54	3455 (36.3)	778 (22.5)	2677 (77.5)	
55-64	2487 (26.1)	501 (20.1)	1986 (79.9)	
≥ 65	714 (7.5)	154 (21.6)	560 (78.4)	
Mean \pm SD	51.46 ± 8.91	50.71 ± 8.82	51.69 ± 8.93	<0.001
Sex				0.019
Male	4428 (46.5)	962 (21.7)	3466 (78.3)	
Female	5094 (53.5)	1210 (23.8)	3884 (76.2)	
Marital status				0.038
Single	277 (2.9)	71 (25.6)	206 (74.4)	
Married	8616 (90.5)	1967 (22.8)	6649 (77.2)	
Widow	517 (5.4)	100 (19.3)	417 (80.7)	
Divorced	112 (1.2)	34 (30.4)	78 (69.6)	
Education (years)				0.001
Illiterate	1582 (16.6)	321 (20.3)	1261 (79.7)	
1-5	3004 (31.5)	654 (21.8)	2350 (78.2)	
6-12	4343 (45.6)	1037 (23.9)	3306 (76.1)	
University	593 (6.2)	160 (27)	433 (73)	
Mean \pm SD	6.61 ± 4.54	6.98 ± 4.60	6.50 ± 4.52	<0.001
Employment				0.015
Unemployed	4307 (45.2)	1032 (24)	3275 (76)	
Employed	5215 (54.8)	1140 (21.9)	4075 (78.1)	
Habitat				<0.001
Urban	4352 (45.7)	904 (20.8)	3448 (79.2)	
Rural	5170 (54.3)	1268 (24.5)	3902 (75.5)	
Wealth score index				<0.001
Low-income	3174 (33.3)	667 (21)	2507 (79)	
Middle-income	3174 (33.3)	694 (21.9)	2480 (78.1)	
High-income	3174 (33.3)	811 (25.6)	2363 (74.4)	
Mean \pm SD	0 ± 1	0.08 ± 1.02	-0.03 ± 1.00	<0.001
BMI (kg/m ²)				0.013
Underweight	130 (1.4)	27 (20.8)	103 (79.2)	
Normal	2509 (26.3)	527 (21)	1982 (79)	

Overweight	3777 (39.7)	885 (23.4)	2892 (76.6)	
Obese	3106 (32.6)	733 (23.6)	2373 (76.4)	
Mean ± SD	28.13 ± 5.12	28.38 ± 5.16	28.06 ± 5.10	0.009
Smoking				0.164
Yes	2348 (24.7)	511 (21.8)	1837 (78.2)	
No	7174(75.3)	1661(23.2)	5513(76.8)	
Hookah smoking				0.650
Yes	1401 (14.7)	313 (22.3)	1088 (77.7)	
No	8121(85.3)	1859(22.9)	6262(77.1)	
Opium consumption				0.571
Yes	666 (7.0)	146 (21.9)	520 (78.1)	
No	8856(93)	2026(22.9)	6830(77.1)	
Alcohol consumption				0.043
Yes	1277 (13.4)	263 (20.6)	1014 (79.4)	
No	8245(86.6)	1909(23.2)	6336(76.8)	
Hypertension				0.030
Yes	4266 (44.8)	929 (21.8)	3337 (78.2)	
No	5256(55.2)	1243(23.6)	4013(76.4)	
Diabetes				0.904
Yes	2358 (24.8)	540 (22.9)	1818 (77.1)	
No	7164(75.2)	1632(22.8)	5532(77.2)	
Vitamin D supplement use during the past year				0.002
Yes	1547(16.2)	305(19.7)	1242(80.3)	
No	7975(83.8)	1867(23.4)	6108(76.6)	

SD: Standard Deviation; BMI: Body Mass Index

Table 2. Prevalence of vitamin D deficiency based on the physical activity of the participants.

Physical activity	Prevalence of vitamin D deficiency (≤12 ng/mL)	
	n / N	%
Tertile 1 (Low)	799 / 3174	25.2
Tertile 2 (Moderate)	713 / 3174	22.5
Tertile 3 (High)	660 / 3174	20.8
<i>P</i> for trend ^a	<0.001	

^a Cochran–Armitage test for trend

Table 3. The effect of physical activity on vitamin D deficiency among the participants in the PERSIAN Guilan cohort study.

	Physical activity				
	Low		Moderate		High
Model 1	1.28 (1.14–1.44)	<0.001	1.10 (0.98–1.24)	0.106	1 (Ref.)
Model 2	1.30 (1.15–1.46)	<0.001	1.11 (0.99–1.25)	0.081	1 (Ref.)
Model 3	1.30 (1.15–1.46)	<0.001	1.11 (0.99–1.25)	0.076	1 (Ref.)
Model 4	1.15 (1.01–1.31)	0.038	1.01 (0.89–1.15)	0.841	1 (Ref.)

Values are presented as OR (95% CI)

Model 1: Unadjusted model

Model 2: Adjusted for vitamin D supplement use

Model 3: Adjusted for hypertension and diabetes patients

Model 4: Adjusted for vitamin D supplement use and sociodemographic characteristic

4. Discussion

Despite pointing to a positive association between physical activity and vitamin D status in studies [29,30], it is still unclear whether this relationship is caused by biological mechanisms or is due to confounding by other lifestyle-related factors [31]. In current study, we examined serum 25(OH)D levels in the PERSIAN Guilan Cohort population, taking into account a wide range of confounding factors. The results of several models showed a positive association between physical activity and serum vitamin D status. Limited physical activity and a sedentary lifestyle are well known causes of obesity [32]. Studies have found an inverse relationship between obesity defined by BMI, fat mass, or waist circumference and vitamin D status [33,34], reversed by weight loss [35]. Physical activity ultimately leads to weight loss and fat tissue

redistribution through increased lipolysis. Considering the fat-soluble nature of vit D, this hypothesis can partially justify the increase in its level following activity [36]. One of the other proposed mechanisms is the effect of physical activity on reducing serum phosphate levels [37]. There is evidence that phosphate suppresses active vit D production through a negative feedback loop [38]. Another mechanism is the increase in the secretion of parathormone hormone following the decrease in ionized calcium during physical activity, which leads to the activation of renal calcitriol synthesis [37]. Also, strong evidence has been obtained of the role of skeletal muscles as a storehouse of 25(OH)D in the body [39]. This helps to maintain the vit D serum level by releasing it in the winter seasons when the amount of solar UVB light is limited [39].

On the other hand, there seems to be a bidirectional relationship between vit D status and physical activity,

as there is evidence that vit D is effective in improving muscle function and a person's performance during activity. Calcium and 25(OH)D may prevent muscle fatigue by regulating the biosynthesis of creatine kinase, lactic acid dehydrogenase, troponin I, and hydroxyproline [40].

In another study, through imaging and biopsy findings, muscle atrophy was also associated with vit D deficiency [41]. Activating vit D receptors in skeletal muscle fibers can lead to cell proliferation and muscle mass growth [42]. So far, the evidence linking chronic diseases, particularly diabetes and hypertension, to vitamin D status has been equivocal.

Various mechanisms and theories have been proposed, but due to the multifactorial nature of these diseases, the definitive effect remains in an aura of uncertainty [43,44]. The high rate of diabetes (24.8%) and hypertension (44.8%) in the current study population made it important to adjust the possible effect of their interventions in a separate model. As a result of this adjustment, it was found that people with limited physical activity were 30% more likely to have vitamin D deficiency. Previous studies have suggested the possibility that a number of sociodemographic, lifestyle, and metabolic health factors may influence vitamin D status. The main factors mentioned were: age group [45,46], sex [47], marital status [31], education level [47] and lifestyle factors such as BMI [29,48], physical activity [49,50], smoking [51], alcohol consumption [52], vit D supplements [31] and diet [53].

In addition, in the present study, we tried to consider all possible intervenors by considering factors such as wealth score index, hookah smoking, place of residence (urban or rural) and opium consumption. Despite the adjustment of all mentioned factors in a separate model, we still saw a higher chance of vitamin D deficiency in people with limited physical activity. The strengths of our study were the large community of participants and the assessment of physical activity with a detailed questionnaire. In addition, a wide range of sociodemographic, behavioral, and health-related variables were considered. Another strength was the use of serum 25(OH)D concentration to indicate vitamin D status. Serum 25(OH)D concentration reflects dietary and supplemental as well as cutaneous vitamin D synthesis. However, this study also had limitations, including its cross-sectional nature, which prevented causal conclusions, so determining cause and effect needs further investigation. another limitation was the timing of blood sampling, which occurred throughout the year and not during a specific season. Also, there is a recall bias in evaluating physical activity using the questionnaire method. In addition, we could not evaluate the participants' exposure to sunlight during physical activity. Further interventional studies are needed to investigate this relationship by considering other factors affecting vit D, including gonadal hormones and a more comprehensive assessment of dietary patterns.

In this study, we addressed another positive aspect of physical activity, including its effect on increasing serum vitamin D status. A positive effect of physical activity on increasing vitamin D status among participants suggests that regular physical activity may contribute to improved vitamin D status, which is important for various aspects of health, such as bone health, immune function, and overall well-being.

Authors' contributions

Concept development (provided idea for the research): MJ, FJ and FMGH. Design (planned the methods to generate the results): SM, MN and FJ. Supervision (provided oversight, responsible for organization and implementation): MJ, FMGH and AE. Data collection/processing (responsible for experiments, patient management, organization, or reporting data) and data analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): SM and FJ. Literature search (performed the literature search and writing of the manuscript): MJ and AE. Drafting the manuscript (responsible for writing a substantive part of the manuscript): MJ, FJ, AE, SM, MN, FMGH. All authors read and approved the final version of article.

Conflict of interest

No potential conflict of interest was reported by the authors.

Ethical declarations

This study was approved by the ethics committees of the Guilan University of Medical Sciences [IR.GUMS.REC.1402.600]. Informed consent obtained from all of the participants.

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