Associations between vitamin D Iinsufficiency, health beliefs, and quality of life in metabolic syndrome: A northeastern Taiwanese community study

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ABSTRACT

Background and Objectives: The impact of Vitamin D on health-related quality of life (HRQoL) and health beliefs in specific populations, such as Taiwanese adults, remains underexplored. Metabolic syndrome (MetS) and vitamin D insufficiency (VDI) are prevalent global health concerns. However, the association between VDI and MetS is still inconclusive, particularly in relation to HRQoL within the framework of the health belief model (HBM). This study aimed to investigate the associations among VDI, HBM constructs, HRQoL, and MetS in a community-based population of Taiwanese adults. **Methods and Study Design:** This cross-sectional study recruited 1015 Taiwanese patients aged ≥30 years between August 2020 and July 2023. Sociodemographic data, anthropometric variables, and vitamin D concentration, defined as 25 (OH) D concentrations, were acquired from medical records. Data regarding health beliefs and HRQoL were obtained through structured questionnaire. **Results:** The mean 25(OH)D concentration was 29.59 ± 10.80 ng/mL and the overall prevalence of VDI was MetS was 54.9%. There was no significant difference in the prevalence of MetS between the VDI and sufficiency groups. Multivariate analysis revealed that the factors associated with VDI prevalence were female sex, age< 65 years, college and above education attainment, high LDL concentration, no alcohol use, and low scores on the emotional role item of HRQoL. **Conclusions:** VDI was not significantly associated with MetS prevalence or HBM constructs. However, key risk factors for VDI should be integrated into targeted health initiatives to address modifiable risk factors and improve vitamin D status.

Key Words: vitamin D insufficiency, quality of life, health belief, metabolic syndrome, public health

INTRODUCTION

The increasing incidence of vitamin D insufficiency (VDI) has recently attracted global health attention.[1, 2] Vitamin D, a lipid-soluble vitamin with a steroidal structure, is an essential nutrient that sustains human health. It plays a key role in regulating calcium metabolism.[3] Vitamin D is synthesized from cholecalciferol in the skin exposed to ultraviolet light and is subsequently converted into its active form, calcitriol, via modification of the liver and kidney.[4–5] Vitamin D levels are influenced by a multitude of factors, including age, sex, lifestyle choices (such as smoking and physical activity), dietary habits, sun exposure, and sun-protective behaviors. Additionally, genetic variations in vitamin D-metabolizing enzymes and hepatic 25-hydroxylation efficiency play crucial roles.[4–10] Notably, low vitamin D levels have been observed to correlate with several components of metabolic syndrome (MetS), a cluster of conditions including abdominal obesity, hypertension, dyslipidemia (characterized by elevated triglycerides and reduced HDL-cholesterol), and impaired glucose metabolism.[5, 11–25] For instance, Mansouri et al. reported an inverse association between serum vitamin D levels and the presence of abdominal obesity, hypertension, and abnormal glucose homeostasis in a sample of 352 Iranian individuals aged 35 or older.[14] However, their study did not find a significant association between serum vitamin D levels and the overall diagnosis of metabolic syndrome.[14] Therefore, we hypothesized that population targeting, study design, and certain variables such as sociodemographic factors, personal behavior, and health belief behaviors could contribute to inconsistent results among studies.

Healthy behavioral interventions have been shown to exert significant positive effects in managing abdominal obesity and improving elevated levels of blood pressure, triglycerides, and fasting blood glucose. 13 Consequently, such interventions may serve a critical role in enhancing vitamin D status among populations at increased risk Effective health interventions require robust theoretical frameworks to address the persistent gap between health knowledge and behavior. The Health Belief Model (HBM) provides a structured lens for understanding the cognitive factors—such as perceived susceptibility, severity, benefits, barriers, and self-efficacy—that influence dietary behavior.[26] As a key lifestyle determinant, dietary behavior significantly impacts health outcomes.[27] Despite widespread nutritional awareness, suboptimal practices—particularly concerning vitamin D—persist, reflecting a knowledge-behavior disconnect. HBM is especially relevant to vitamin D due to underestimation of deficiency risks and consequences. HBM-based interventions effectively address these perceptions, improving dietary behaviors and health outcomes.

Having a higher level of self-efficacy or health belief in one's ability to make positive lifestyle changes and being more likely to engage in healthy behaviors may decrease the risk of MetS and hypovitaminosis D.[28–31] Chen et al. analyzed 287 Taiwanese individuals who purchased vitamin D from pharmacies and found that the perceived benefit was linked to the intention of vitamin D supplementation.[32] Impaired HRQoL, as assessed by the SF-36 questionnaire, was found in patients with MetS.[12] A systematic review conducted by Guzek et al. reported the positive effect of vitamin D supplementation on the mental health of patients with diabetes mellitus,[33] whereas a meta-analysis conducted by Hoffmann et al. showed that the effect of vitamin D supplementation on HRQoL was small, short-term, and limited in certain disease populations.[34] Although lower levels of vitamin D were found in patients in some study,[14] the association between hypovitaminosis D and HRQoL, or the effect of vitamin D supplementation on HRQoL, remains debated.[29, 35] Therefore, the interplay between vitamin D status, MetS, health beliefs, and quality of life deserves further investigation. This study aimed to investigate the prevalence of VDI and its associations with metabolic syndrome, HRQoL, and constructs of the HBM, as well as to identify potential determinants of VDI among community-dwelling adults.

MATERIALS AND METHODS

Design

This cross-sectional study enrolled residents who underwent a health assessment program between August 2019 and December 2022 at Chang Gung Memorial Hospital (CGMH), Keelung, Taiwan. Participants were excluded from the study if they had a prior diagnosis of any of the following medical conditions: major gastrointestinal disorders, autoimmune diseases, end-stage renal failure, liver cirrhosis, heart failure, diabetes mellitus, or dementia. Additionally, individuals taking regular medications known to significantly affect metabolism and weight, such as steroids or megestrol acetate, were also excluded. We explained the purpose, procedures, rights, and confidentiality of the research study to the participants. All the participants signed a consent form in accordance with the Declaration of Helsinki. The study protocol (institutional review board approval number: 201800479B0C501; 202200468B0C501) was approved by the local research ethics committee of the Chang Gung Memorial Hospital in Taiwan, ROC. Informed consent was obtained from all the participants and/or their legal guardians.

Patient population and sampling

At the baseline survey, all participants completed physical examinations, laboratory tests, and questionnaires containing queries on their current medication and history of disease through one-on-one interviews. To ensure that the participants had the requisite cognitive ability, we asked three fact-based questions, including the current year, a basic math addition, and the correct day of the week after the identification. If any of these three questions were answered incorrectly, the participant questionnaires were considered ineligible. Two research nurses simultaneously checked each participant's completed questionnaires. From the 1126 participants recruited, 111 cases (69 women and 42 men) were excluded due to failure of fact-based questions because of specific disabilities. Ultimately, 1,015 participants (638 women and 377 men) completed all the required study assessments, yielding a response rate of 90.1%.

Assessment of sociodemographic variables

Sociodemographic data, including age; sex; level of educational attainment; smoking habits; alcohol consumption; betel nut usage; diet style; and history of obesity, diabetes, hypertension, and CVD, were collected. Educational attainment was classified into two groups: < 12 years (high school) and > 12 years (college and above). Smoking exposure was considered affirmative if the participants were current or former smokers. Alcohol consumption was considered positive if the participants reported consuming four or more drinks per week. Habits of betel nut use were considered affirmative if participants indicated any usage during the previous year. Diets were classified into vegetarian and nonvegetarian groups.

Assessment of anthropometric variables

Anthropometric data including blood pressure, weight, height, BMI, and waist circumference (WC) were recorded for each participant. Body height (m) and weight (kg) were measured by an automatic height-weight scale to the nearest 0.1 cm and 0.1 kg respectively. Systolic and diastolic BP were measured in a sitting position twice, after 5 min of rest, using validated and calibrated electronic sphygmomanometers. BMI was calculated as weight divided by the square of height (m). WC was used to examine central adiposity and was measured to the nearest 0.1 cm at the midpoint between the 12th rib and the right anterior superior iliac spine using an unstretched tape meter. The biochemical data including levels of fasting glucose (Glucose, AC), glycated hemoglobin (HbA1C), triglyceride (TG), total cholesterol, HDL-C, low-density lipoprotein cholesterol (LDL-C), C reactive protein (CRP), 25(OH)D and insulin resistance measured by homeostasis model assessment-insulin resistance (HOMA_IR) were examined by an autoanalyzer (Beckman, USA) in the CGMH central laboratory in Keelung. All data were collected consistently by two qualified researchers who were trained by a certified International Society for the Advancement of Kinanthropometry specialist before this study to collect data in a standardized manner.

Diagnostic criteria for metabolic syndrome and vitamin D insufficiency

According to the modified National Cholesterol Education Program-Adult Treatment Panel III, MetS was defined as the presence of three or more of the following conditions: (i) hypertension, systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg, or the use of antihypertensive agents; (ii) hyperglycemia, fasting blood glucose level ≥100 mg/dL, or the use of antihyperglycemic agents; (iii) low serum HDL-C, ≤ 40 mg/dL for men or ≤ 50 mg/dL for women; (iv) hypertriglyceridemia, TG level ≥ 150 mg/dL; and (v) abdominal obesity, WC ≥ 90 cm for men and ≥80 cm for women.[36-38]

The laboratory used internal quality controls for the measurement of 25(OH)D levels to assess the vitamin D status. VDI was defined as 25 (OH) D concentrations with 30 ng/mL and above, while its insufficiency was defined as 25 (OH) D below 30 ng/mL. The cut-off value was based on the Endocrine Society Clinical Practice recommendations.[39]

Assessment of health belief and health-related quality of life

The concept of health belief is used to examine motivations for adapting health-related behaviors and assess health behavior interventions. According to the existing literature,[40] the Health Belief Model (HBM) questionnaire was designed and measured using a health belief 9-item scale representing the six dimensions of the HBM: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, self-efficacy, and cue to action. This scale produces a score from 1 (“strongly disagree”) to 5 (“strongly agree”), with the total sums of scores ranging from 9 to 45.

HRQoL was evaluated by SF-36 questionnaire.[29] The SF-36 questionnaire includes 36 questions related to an individual’s QOL, which are summarized in two component summary scores: the Physical Component Summary (PCS) and the Mental Component Summary (MCS). Based on exploratory factor analysis of the eight SF-36 subscales related to physical health (general health perception [GH], physical functioning [PF], role physical [RP], bodily pain [BP]) and mental well-being (role emotional [RE], social functioning [SF], vitality [VT], and mental health [MH]). Higher scores ranging from 0 to 100 indicate better health.[41–42]

Expert validation and data collection

A structured questionnaire and direct objective measures, including demographic data, anthropometric data, health beliefs, and health-related quality of life, were used to collect data. We invited seven experts (two cardiologists, two endocrinologists, one family medicine physician, and two senior nursing practitioners, who had all practiced for over 13 years) to review the questionnaire’s integrity, suitability, and diction. They conducted a content validity test and obtained a content validity index of 0.93. Under the guidance of the study nurses, who were specially trained by our seven experts, each participant took approximately 30–35 min to complete and provide their medical records, including details about their current medications. Physical examinations included data on body height, body weight, WC, and BP. Blood samples were collected after an overnight fast.

Data analysis

All data obtained were analyzed using the Statistical Package for Social Sciences software, version 25.0 for Windows. Descriptive statistics were computed for demographic factors, physiological/biochemical measurements, health beliefs, and HRQoL data. The Kolmogorov–Smirnov test for normality was conducted for all continuous variables. The independent t-test for normally distributed continuous variables, nonparametric Mann–Whitney U test for non-normally distributed continuous variables, and chi-square test for categorical data were used. Variables with statistical significance ($p < 0.05$) in the univariate analysis were entered multivariate logistic regression to assess the variables associated with the occurrence of VDI. A multivariate linear regression model was fitted to estimate the association between the two domains (PCS and MCS) of HRQoL and sociodemographic and health belief variables in the participants with VDI.

RESULTS

Characteristics of participants

Table 1 shows the baseline sociodemographic characteristics of the participants. A total of 1,015 individuals participated in the study, nearly three-fourths of whom were younger than 65 years. The average age was 59.53 ± 9.95 years. Most participants were female (62.9%) and had graduated high school (78.5%). The mean BMI was 25.23 ± 3.87 kg/m^2 but there was significant BMI difference between men and women ($p < 0.001$). Approximately half of the participants developed MetS (43.9%) and only a few of them were vegetarians (3.1%).

The mean 25(OH)D level was 29.62 ± 10.99 ng/mL in the cohort, and female participants had a lower 25(OH)D level than male participants ($p < 0.001$). Furthermore, 558 participants had VDI, with a prevalence of 55.0%. Nearly half of the participants in the insufficiency group presented MetS (256/558, 45.9%). The VDI group was younger, had higher education attainment, less exposed to smoking and alcohol drinking, and showed significantly higher values of BMI, total cholesterol, LDL-C, insulin, and HOMA_IR than the sufficiency group ($p < 0.05$). Nonetheless, the percentages of abdominal waist circumference, blood pressure, fasting glucose, HbA1C, TG, and HDL-C levels did not differ between the two groups (Table 1).

Association between vitamin D status, HBM, and HRQoL

Although there was no overall score difference in HBM assessment between the VDI and sufficiency group, the participants in the insufficiency group had a higher score in the perceived benefits ($p = 0.014$) and perceived barriers ($p = 0.020$), and a lower score in cue to action ($p = 0.040$) as compared to those the sufficiency group (Table 1)

The mean scores of PCS and its associated subscales in the Vitamin D insufficiency group were lower than the sufficiency group, the GH item reached a statistical difference between the two groups ($p = 0.007$, Table 1). Notably, mean scores on the MCS and its associated subscales (VT, SF, RE, and MH) were significantly lower in the VDI group than in the sufficiency group (Table 1). Multivariate analysis further showed that female sex, age < 65 years, education with college and above, and high LDL concentration were risk factors, while alcohol consumption and high role-emotional score of HRQoL were protective factors against the occurrence of VDI (Table 2).

We conducted further analysis on 558 patients with vitamin D insufficiency (VDI) to identify factors associated with this nutritional deficiency. Table 3 presents the results of univariate and multivariate analyses examining predictors of the PCS scores. In the multivariate model, three variables emerged as significant predictors of physical functioning. Age was inversely associated with PCS scores, with each additional year corresponding to a 1.991-point decrease (95% CI: –3.614 to –0.367; $p = 0.016$). Current smoking status was unexpectedly associated with higher PCS scores ($\beta = 2.169$; 95% CI: 0.129 to 4.209; $p = 0.037$). Within the framework of the health belief model, perceived barriers showed a significant negative association with PCS scores ($\beta = -0.053$; 95% CI: –0.095 to –0.012; $p = 0.012$). No significant associations were observed for sex, educational attainment, BMI, or perceived self-efficacy in the adjusted model. Similarly, Table 4 presents findings related to the MCS scores. Higher educational attainment and self-efficacy were positively associated with MCS scores, whereas perceived barriers were negatively associated.

DISCUSSION

The inverse correlation between Vitamin D concentration and the development of MetS could be explained by the dependence of insulin production in pancreatic β cells on Vitamin D and its receptor interaction,[11] obesity resulting in more sequestration of vitamin D in adipose tissue,[43] and greater volumetric dilution of serum 25(OH)D level, less sun exposure, poor dietary habits, and varied genetic expression of enzymes involving vitamin D metabolism.[17, 44] The study found that 54.9% of the participants had vitamin D insufficiency (VDI), while 43.9% met the diagnostic criteria for metabolic syndrome (MetS); however, no statistically significant difference was observed between these groups. Multivariate analysis revealed associations between the risk of VDI and several sociodemographic variables, including sex, age, educational attainment, and alcohol consumption. Nevertheless, due to the cross-sectional design of this study, causal relationships or the directionality of these associations cannot be determined. These findings underscore the importance of considering population characteristics, study designs, and clinical contexts when evaluating inconsistencies in studies examining the relationship between vitamin D status and MetS.

The present study identified factors associated with vitamin D insufficiency (VDI), which were categorized into potential risk factors (female sex, age < 65 years, college education or higher, and elevated serum LDLconcentrations) and potential protective factors (alcohol use and better emotional role functioning in HRQoL). These findings align with those reported in previous studies. For instance, factors such as female sex, younger age, and higher educational attainment have been observed in one U.S.-based study and two Taiwanese studies. These associations have been explored from various perspectives, including differences in lifestyle, occupation, physical activity, residency location, sun exposure, and metabolic profiles.[7, 32, 45–49] Recent research has shown a positive association between serum vitamin D levels and alcohol use 48 suggesting a protective role in reducing the development of VDI. Another possible reason for the protective function of alcohol consumption could be that Taiwanese people often eat protein-rich food and wine pairing when drinking alcohol and gain resources for vitamin D supplementation.

We analyzed health belief behavior classified by factors identified for risk of VDI accordingly, and found the following: women had lower scores of the perceived barrier but higher scores of self-efficacy than men (Supplementary Table 1); participants with age < 65 years or with college and above education attainment had higher scores of perceived susceptivity, perceived severity, perceived benefit, and cue-to-action than those with age ≥ 65 years or with high school education (Supplementary Table 2 and Table 3); participants exposed alcohol drinking had higher score of perceived barrier (Supplementary Table 5), whereas participants with higher RE scores had lower score of the perceived barrier (Supplementary Table 6), whereas participants aged < 65 years or with college and above education attainment had better quality scores in physical health perceive but worse in mental health than those with age ≥ 65 years or with high school education (Supplementary Table 2 and Table 3); participants with higher LDL level presented better physical functioning than those with lower LDL concentration (Supplementary Table 4); participants exposed alcohol drinking had similar HRQoL to those with no alcohol exposure, whereas participants with higher RE scores had better HRQoL including all domains of physical health, mental well-being, PCS and MCS than those with lower RE scores (Supplementary Table 5 and Table 6).

Hence, except for female sex and alcohol exposure, participants with factors such as age < 65 years, college or higher education attainment, and higher LDL and RE scores had better HRQoL in terms of either physical or mental health. Finally, there was an intimate association between HBM and HRQoL (Supplementary Table 7). Although this link could partially explain why certain items of the HBM or HRQoL that were significantly detected in the univariate analysis were no longer statistically meaningful in the multivariate analysis, these unadjusted comparisons remain cautiously interpreted.

The other salient feature of the present study was the identification of factors that were associated with HRQoL in participants with VDI, including age, smoking, blood pressure, perceived barriers of the HBM for PCS, educational attainment, perceived barriers, and self-efficacy of the HBM for MCS (Tables 3 and 4). Our regression analyses identified distinct sociodemographic and psychosocial predictors of both physical and mental HRQoL. Increasing age was significantly associated with lower PCS scores, aligning with previous findings on age-related declines in physical functioning. Notably, smoking status was positively associated with PCS scores—an unexpected result that may reflect residual confounding or underlying cultural and behavioral factors, and thus warrants further investigation. Within the HBM framework, perceived barriers consistently demonstrated a strong inverse association with both PCS and MCS scores, suggesting that individuals who perceive greater obstacles to engaging in health-promoting behaviors may experience reduced physical and mental well-being. In contrast, higher levels of self-efficacy were positively associated with MCS scores, underscoring the protective role of personal agency in maintaining mental health. Additionally, educational attainment was a significant determinant of mental health status, with lower levels of education linked to poorer MCS scores. These findings highlight the importance of addressing both structural determinants (e.g., education) and modifiable psychological factors (e.g., perceived barriers, self-efficacy) in efforts to enhance the overall quality of life in individuals with VDI. Moreover, to our knowledge, the present finding provides preliminary evidence suggesting a close link between health beliefs and HRQoL in this population. In this context, perceived barriers reflect an individual's evaluation of obstacles to engaging in health-promoting behaviors, such as vitamin D supplementation, increased sunlight exposure, or dietary modifications to improve vitamin D status. Patients with VDI may lack adequate knowledge about vitamin D, hold misconceptions about supplementation, or underestimate the benefits of behavior change. Targeted interventions—such as tailored nutrition education, improved accessibility to vitamin D supplements, and efforts to correct misinformation—may help reduce perceived barriers, promote healthier behaviors, and ultimately improve vitamin D levels and HRQoL.[50] Hence, public health promotion, such as smoking cessation, blood pressure monitoring, and health knowledge improvement via adopting health belief behaviors, is a practical strategy for improving the quality of life of people with hypovitaminosis D.

The present study had some limitations. First, selection bias was inevitable in this cross-sectional study. Our results were obtained from a community population who actively and voluntarily sought medical counseling and complied with health guidance; thus, their external validity in the general population and different social conditions, such as staying at nursing homes, living alone with no assistance, and unwillingness to go out, requires determination. Second, causal inferences underlying the observed associations could not be drawn in a cross-sectional study, and reverse causation may be present in our results. Despite the methodological limitations of this study, the observed associations between the potential independent variables and vitamin D insufficiency underscore the importance of future longitudinal research to clarify underlying causal relationships. As there is a lack of disease-specific measurements for vitamin D insufficiency, our study applied generic measurements for HBM and HRQoL assessments and offered the only viable option at present. Different measurements used to assess the HBM and HRQoL may have varied outcomes. Third, we were unable to include medication, physical activity, and comorbidity status as covariables because these variables influence vitamin D metabolism.[51–53]

Conclusions

Our data demonstrate that the risk factors associated with VDI were female sex, age < 65 years, college and above education attainment, high LDL concentration, no alcohol use, and low scores on the role-emotional item of the HRQoL. Moreover, age, smoking, education level, blood pressure, perceived barriers, and self-efficacy of the HBM were correlated with the PCS or MCS of HRQoL in people with VDI. From our own perspective, a prospective and longitudinal follow-up study recruiting all-comers from varied health conditions using disease-specific measurements and analyzing all potential covariates is essential to determine the causal relationship between VDI, HBM, and HRQoL. Tailored health promotion programs to ameliorate the prevalence of VDI, established by local governments and health institutes, should consider the risk factors.

SUPPLEMENTARY MATERIALS

All supplementary tables and figures are available upon request from the editorial office, and are also accessible on the journal’s webpage (apjcn.qdu.edu.cn).

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare that they have no competing interests.

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Table 1. Characteristics of the study participants (N=1,015)

Variables	Overall (N=1015)	VitD insufficiency (n=558)	VitD sufficiency (n=457)	p*
25 (OH)D (ng/mL)	29.62 ± 10.99	21.98 ± 5.33	38.89 ± 8.21	<0.001
Sex				<0.001
Men	377 (37.1)	149 (26.7)	228 (49.9)	
Women	638 (62.9)	409 (73.3)	229 (50.1)	
Age (Mean)	59.53±9.95	57.70 ± 10.34	61.76 ± 8.97	<0.001
Age				<0.001
<65years	750 (73.9)	452 (81.0)	298 (65.2)	
65 years above	265 (26.1)	106 (19.0)	159 (34.8)	
Educational attainment				0.001
High school	797 (78.5)	416 (74.6)	381 (83.4)	
College and above	218 (21.5)	142 (25.4)	76 (16.6)	
Metabolic syndrome				0.169
Yes	446 (43.9)	256 (45.9)	190 (41.6)	
No	569 (56.1)	302 (54.1)	267 (58.4)	
Abnormal waist†				0.157
Yes	478 (47.1)	274 (49.1)	204 (44.6)	
No	537 (52.9)	284 (50.9)	253 (55.4)	
Diet (Non-vegetarian)	984 (96.9)	536 (96.1)	448 (98.0)	0.069
Smoking (yes)	187 (18.4)	76 (13.6)	111 (24.3)	<0.001
Drinking (yes)	409 (40.3)	199 (35.7)	210 (46.0)	0.001
Betel nut usage (yes)	47 (4.6)	20 (3.6)	27 (5.9)	0.080
BMI (Mean)	25.23 ± 3.87	25.55 ± 4.19	24.85 ± 3.39	0.004
BMI≧24	602 (59.3)	344 (61.6)	258 (56.5)	0.094
Weight	63.93 ± 12.07	64.84 ± 12.86	64.04 ± 11.03	0.790
Systolic blood pressure	132.75 ± 26.23	133.61 ± 31.59	131.69 ± 17.57	0.247
Diastolic blood pressure	79.28 ± 11.22	79.73 ± 11.53	78.72 ± 10.82	0.152
Glucose_AC	107.83 ± 33.18	108.13 ± 36.45	107.47 ± 28.73	0.751
HbAlC (mmol/mL)	6.02 ± 1.05	6.04 ± 1.12	5.99 ± 0.97	0.434
Insulin, mU/L	9.15 ± 7.31	9.71 ± 7.15	8.45 ± 7.46	0.006
HOMA_IR	2.58 ± 2.78	2.77 ± 2.96	2.34 ± 2.54	0.013
Total cholesterol (mg/dL)	207.52 ± 48.09	210.91 ± 53.19	203.38 ± 40.70	0.013
LDL-C (mg/dL)	122.55 ± 34.20	125.24 ± 35.29	119.28 ± 32.55	0.006
HDL-C (mg/dL)	56.73 ± 15.53	56.32 ± 14.84	57.23 ± 16.33	0.355
Triglyceride (mg/dL)	140.22 ± 343.86	153.97 ± 454.31	123.43 ± 101.51	0.159
Health belief	231.84 ± 22.45	232.33 ± 21.78	233.47 ± 23.45	0.405
Perceived susceptibility	26.31 ± 5.32	26.44 ± 5.53	26.16 ± 5.03	0.461
Perceived severity	28.64 ± 5.47	28.76 ± 5.59	28.50 ± 5.32	0.516
Perceived benefits	44.15 ± 5.50	44.54 ± 5.51	43.69 ± 5.44	0.014
Perceived barriers	33.35 ± 11.58	44.69 ± 5.52	43.71 ± 5.42	0.020
Self-efficacy	65.12 ± 9.72	65.05 ± 10.01	65.20 ± 9.36	0.807
Cue to action	35.26 ± 5.40	34.94 ± 5.51	35.64 ± 5.26	0.04
Health-related Quality of Life				
PF	88.84 ± 16.10	88.70 ± 15.90	89.02 ± 16.36	0.755
RP	82.69 ± 34.49	81.46 ± 35.37	84.19 ± 33.37	0.210
BP	80.33 ± 21.57	79.76 ± 21.77	81.03 ± 21.34	0.354
GH	64.49 ± 20.78	62.91 ± 21.10	66.43 ± 20.22	0.007
VT	69.53 ± 20.23	68.01 ± 20.84	71.38 ± 19.32	0.009
SF	91.80 ± 14.59	90.79 ± 15.75	93.01 ± 12.97	0.018
RE	87.57 ± 30.08	85.25 ± 32.61	90.40 ± 26.42	0.007
MH	74.95 ± 17.93	73.66 ± 18.47	76.54 ± 17.12	0.011
PCS	52.09 ± 7.24	51.91 ± 7.37	52.32 ± 7.07	0.385
MCS	51.87 ± 9.01	50.98 ± 9.52	52.96 ± 8.22	0.001

Vit D, vitamin D; HBM, health belief model; HRQoL, health-related quality of life; PF, physical functioning; RP, physical role; BP, bodily pain; GH, general health; VT, vitality; SF, social functioning; RE, emotional role; MH, mental health; PCS, Physical Component Summary; MCS, Mental Component Summary

Variables expressed as number (%) or mean ± standard deviations

†abnormal waist defined as waist circumference ≥ 90 cm for men and ≥ 80 cm for women.

*$p < 0.05$, statistically significant.

Table 2. Logistic regression analysis of risk factors for vitamin D insufficiency among 1,015 participants in the entire study

Variable	OR (95% CI)	*p**
Age (ref: <65years)	0.46(0.333 to 0.652)	<0.001
Gender (ref: women)	0.306 (0.213 to 0.44)	<0.001
Educational attainment (ref: High school)	2.211 (1.529 to 3.197)	<0.001
Smoking (ref: no)	1.09 (0.711 to 1.67)	0.694
Drinking (ref: no)	0.73 (0.54 to 0.986)	0.040
Insulin, mU/L	0.992 (0.943 to 1.044)	0.761
Total cholesterol (mg/dl)	0.998 (0.993 to 1.002)	0.303
LDL-C (mg/dl)	1.008 (1.002 to 1.015)	0.013
HOMA_IR	1.127 (0.981 to 1.295)	0.091
Health belief	-	-
Perceived benefits	0.982 (0.955 to 1.01)	0.197
Perceived barriers	1.004 (0.994 to 1.013)	0.457
Cue to action	1.013 (0.985 to 1.043)	0.366
Health-related quality of life	-	-
GH	0.99 (0.971 to 1.009)	0.287
VT	0.985 (0.963 to 1.008)	0.196
SF	0.983 (0.958 to 1.009)	0.208
RE	0.982 (0.966 to 0.999)	0.043
MH	1.019 (0.997 to 1.041)	0.084

GH: general health; VT: vitality; SF: social functioning; RE: role-emotional; MH: mental health.
*$p < 0.05$, statistically significant

Table 3. Univariate and multivariate analyses to assess variables associated with the physical component summary (PCS) in 558 participants with vitamin D insufficiency

	Univariate	Multivariate		
Variable	*p**	Coefficient	95% CI	*p**
Age (ref: <65years)	0.004	-1.991	-3.614 to -0.367	0.016
Sex (ref: women)	0.037	1.493	-0.209 to 3.195	0.085
Educational attainment (ref: College)	0.004	1.029	-0.434 to 2.492	0.168
Abnormal waist (ref: no)	0.001	-0.122	-1.675 to 1.431	0.877
Diet (ref: non-vegetarian)	0.439			
Smoking (ref: no)	0.002	2.169	0.129 to 4.209	0.037
Drinking (ref: no)	0.912			
Betel nut usage (ref: no)	0.701			
BMI	0.001	-0.129	-0.282 to 0.024	0.098
Body weight	0.29			
Systolic blood pressure	0.402			
Diastolic blood pressure	0.009	0.103	0.046 to 0.159	<0.001
Glucose_AC	0.001	-0.005	-0.044 to 0.034	0.804
HbAlc (mmol/mol)	<0.001	-0.6	-1.712 to 0.513	0.29
Insulin, mU/L	0.001	-0.005	-0.25 to 0.24	0.968
HOMA_IR	<0.001	-0.177	-0.876 to 0.523	0.62
Total cholesterol (mg/dl)	0.916			
LDL-C (mg/dl)	0.411			
HDL-C (mg/dl)	0.281			
Triglyceride (mg/dl)	0.397			
Health belief				
Perceived susceptibility	0.053			
Perceived severity	0.407			
Perceived benefits	0.133			
Perceived barriers	0.025	-0.053	-0.095 to -0.012	0.012
Self-efficacy	0.028	0.03	-0.038 to 0.099	0.385
Cue to action	0.047	0.063	-0.072 to 0.198	0.358

*$p < 0.05$, statistically significant

Table 4. Univariate and multivariate analyses to assess variables associated with the mental component summary (MCS) among the 558 participants with vitamin D insufficiency

	Univariate	Multivariate		
Variable	*p**	Coefficient	95% CI	*p**
Age (ref: <65years)	0.097			
Sex (ref: female)	0.107			
Educational attainment (ref: College)	0.004	-2.006	-3.951 to -0.06	0.043
Abnormal waist (ref: no)	0.246			
Diet (ref: non-vegetarian)	0.911			
Smoking (ref: no)	0.074			
Drinking (ref: no)	0.075			
Betel nut usage (ref: no)	0.230			
BMI	0.237			
Body weight	0.942			
Systolic blood pressure	0.151			
Diastolic blood pressure	0.172			
Glucose_AC	0.05			
HbAlc (mmol/mol)	0.104			
Insulin, mU/L	0.578			
HOMA_IR	0.071			
Total cholesterol (mg/dl)	0.531			
LDL-C (mg/dl)	0.486			
HDL-C (mg/dl)	0.194			
Triglyceride (mg/dl)	0.684			
Health belief				
Perceived susceptibility	0.382			
Perceived severity	0.631			
Perceived benefits	0.512			
Perceived barriers	<0.001	-0.124	-0.18 to -0.068	<0.001
Self-efficacy	0.002	0.081	0.001 to 0.16	0.048
Cue to action	0.819			

*$p < 0.05$, statistically significant