Impact of Community Pharmacist-Led Interventions on Vitamin D Levels and Patient Quality of Life

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Abstract

Background: The widespread deficiency of vitamin D is a recognized public health issue. Maintaining adequate levels of this vitamin is associated with a lower risk of bone fractures, and emerging evidence suggests its preventive role in various diseases.

Objective: This study aimed to investigate whether pharmacist-led intervention and follow-up can enhance patient adherence, improve vitamin D levels, and subsequently lead to an increase in perceived quality of life.

Methods: Multicenter quasi-experimental study with non-probabilistic sampling conducted in ten community pharmacies. Patients were recruited by pharmacists based on symptoms of vitamin D deficiency or current use of vitamin D supplements. Monthly follow-ups were conducted through electronic messaging. Eight months after enrollment, a follow-up survey was carried out via telephone. Outcome variables included socio-demographic data, vitamin D levels, self-perceived quality of life, and physical activity. Data analysis was conducted with a significance level set at $p < 0.05$.

Results: Among the 210 patients, the proportion adhering to the correct vitamin D intake significantly increased from 24.1% to 90.6% ($p < 0.001$) after eight months. Prior to the intervention, only 12.6% of patients had adequate vitamin D levels, which increased to 60.3% following pharmacist intervention (from 21.69 ± 9.32 to 33.13 ± 14.16 ng/mL, $p < 0.001$). Additionally, self-perceived quality of life scores improved from 68.73 ± 18.72 to 76.80 ± 18.85, $p < 0.001$), with 58.5% of patients reporting an improvementin their quality of life.

Conclusion: Pharmacist-led interventions significantly improved patient habits, resulting in increased vitamin D levels. These improvements were associated with a significant increase in patients' perceived quality of life.

Keywords: Vitamin D, Pharmaceutical Care, Community Pharmacy Services, Quality of Life, Public Health.

Key points

This study highlights the indispensable role of the pharmacist as a healthcare agent close and accessible to the patient. Pharmacists have contributed to patients' better understanding of their disease, actively involving them in their own treatment and transforming therapeutic success into a personal achievement.

Background

Vitamin D plays a crucial role in maintaining various aspects of health, particularly in bone metabolism, immune function, and overall well-being. Given its widespread deficiency, especially in older populations, adequate vitamin D levels are essential for preventing conditions such as osteoporosis, cardiovascular disease, and autoimmune disorders[1].

Historically, vitamin D has been associated with the regulation of bone metabolism.Adequate levels protect the geriatric patient by slowing down osteoporotic processes[1]. However, following the discovery of vitamin D receptors in many other systems, emerging evidence has linked vitamin D insufficiency to chronic conditions such as cardiovascular disease, diabetes, and certain immune-related disorders [2,3].

In Spain, the Spanish Society of Endocrinology and Nutrition (SEEN)[4] recommends maintaining serum vitamin D concentrations between 30 and 50 ng/ml. The World Medical Association and the Spanish Society for Bone and Mineral Metabolism Research have defined optimal plasma vitamin D levels as ≥ 30 ng/ml, insufficient levels as between 20 and 30 ng/ml, and deficient levels as below 20 ng/ml [4–6]. Recent studies corroborate that, due to our lifestyle, low sun exposure and metabolic depletion at certain ages, about 80% of patients over 65 are vitamin D deficient or insufficient[7,8].

Controversy remains about whether the effects of vitamin D on non-bone-related systems are truly definitive[9–11]. This relationship can also be observedin patients considered healthy adults[12]. In this context, the role of the pharmacist becomes fundamental. Due to the variety of vitamin D dosages, ranging from 400IU to 50 000IU, with regimens that range from daily, weekly, biweekly, and even monthly doses, patients may become confused[13,14]. A study conducted in Spanish primary care involving 432 patients found that only 20% of those receiving vitamin D treatment had both a clinical indication and confirmed vitamin D

deficiency—criteria used to define therapeutic adequacy in that context[15]. This underscores the frequent lack of alignment between prescribing practices and clinical guidelines. Likewise, many patients do not correctly follow supplementation recommendations due to a lack of knowledge about vitamin D sources and variability in sun exposure[16].

Through targeted actions and activities, pharmacists can improve patient health in cooperation with doctors and other healthcare professionals, resulting in improved quality of life for patients[17–19]. Pharmacists also keep patients permanently informed about new updates related to their pathologies[20,21]. In the context of vitamin D deficiency, pharmacists can play a key role in informing patients about the implications of inadequate levels of this nutrient, particularly in relation to pathologies such as osteoporosis, osteomalacia, and musculoskeletal disorders, where vitamin D plays a well-established role in bone health and fracture prevention. In Spain, vitamin D supplements are available in various formulations with different dosing schedules, including daily, weekly, and monthly regimens. While extended dosing intervals are generally considered to improve adherence, some patients—particularly those who are asymptomatic or perceive vitamin D supplementation as non-essential—may still miss doses. This is especially relevant with monthly regimens, where the long interval between doses increases the chance of forgetfulness. In this context, pharmacists play a critical role in promoting adherence by providing tailored health education and emphasizing the importance of consistent vitamin D intake to prevent both skeletal and non-skeletal complications. These efforts support compliance with treatment guidelines, enhance clinical outcomes, and contribute to a more sustainable healthcare system and improved public health[22–25].

Objective

The aim of this study is to assess the impact of pharmacist's interventions on patient involvement in Vitamin D self-care, vitamin D levels and self-perceived quality of life.

Methods

Study Design

A multicenter, quasi-experimental study using non-probability convenience sampling design was conducted in ten Spanish community pharmacies (Granada and Madrid) across four urban and rural locations over an eight-month period during June 2023 and October 2024. The pharmacies that participated in the study were chosen based on the number of pharmacists working in them to be able to assume the provision of the service (n = 16). All the proposed pharmacies voluntarily agreed to participate, four pharmacies decided not to participantes due to circunstancial problems, and no response was obtained from two pharmacies. Pharmacies were sought in urban and rural locations and in two cities with central and southern locations to avoid bias.

The pharmacist received prior training based on the Spanish Society of Endocrinology and Nutrition criteria for screening patients with vitamin D deficiency/insufficiency, including information on the survey and variables that were considered in the study, the pharmacist's intervention and communication with the primary care physician (PCP) for referral with the request for vitamin D analysis and vitamin D supplementation[4].

Pharmacists identified potential beneficiary patients, offered them the monitoring service, and provided them with education using support materials and additional resources, and they were provided with the survey that was to be passed to them by the pharmacist by telephone at month, month 4 and month 8. Patients were informed that they would receive reminders on the days they were due to take vitamin D, as well as a short monthly video with a maximum duration of one and a half minutes, explaining some of the characteristics of vitamin D

deficiency or insufficiency and the steps to take to improve vitamin D levels. Once month later, patients relieve the first phone call to the first interview through the survey. After four and eight months from the first interview (T0), the pharmacist conducted follow-up phone consultations (second interview (T4) and last interview (T8)) with patients to evaluate any changes in their condition. The survey used with each patient was exactly the same as in the initial interview, except for the socio-health characteristics block, which was eliminated (except for the patient's weight) to avoid duplication data.

Survey Design

The survey had five different blocks: socio-health characteristics, physical activity, diet, medication and perception of health status.The survey questions were taken from the 2020 version of the 'European Health Survey in Spain'[26], selecting the most relevant items to understand patient habits that could contribute to vitamin D deficiency, especially the modules on physical activity, nutrition and medication consumption (sections T, U and P respectively). The last block included a visual analogue scale (VAS) of self-perceived quality of life, extracted from the EuroQol-5D (EQ-5D) questionnaire[27]. The EQ-5D is a useful instrument for application in primary care, valued for its quick and easy administration.

This survey was piloted with a sample of 49 patients[28] and subsequently reviewed by a committee of fifteen experts specializing in various fields related to vitamin D, different from the researchers. The committee consisted of six doctors (Primary Care, Endocrinology, Urology, Rheumatology, and Internal Medicine), five professors from the Faculty of Pharmacy (Departments of Pharmacology, Pharmacy and Pharmaceutical Technology, and Nutrition), three community pharmacists, and a physiotherapist. The audit was carried out using the 'Delphi methodology'. In the dietary section, questions focused on the intake of

products rich in vitamin D, assessing whether an increase in intake could lead to higher vitamin D levels and improved self-perceived quality of life.

The initial interview consisted of 25 questions, including five key areas: socio-demographic characteristics (4 questions), physical activity (4 questions), diet (8 questions), medication (8 questions), and health status (1 question). It was designed for self-administration, using simple and concise language to allow patients to complete the survey at home or in the pharmacy, minimizing interviewer bias and ensuring the collection of data on serum vitamin D levels upon request through the PCP. After three rounds, during which the expert committee reached a consensus, the final version of the survey consisted of 27 questions. Once consensus was reached, the survey design was finalized.

A second and last interview was then designed at four (T4) and eight (T8) months to assess any changes in lifestyle, medication, or dietary habits and to determine whether these changes significantly impacted vitamin D levels and perception of health status. This survey repeated the same questions, with two additional items to assess whether patients had informed their PCP about their participation in the study, whether they received medication reminders correctly, and their evaluation of the videos. These items were positively evaluated by the expert committee.

Supporting Material

During the initial interviews, supplementary material was provided to support the pharmacist's intervention and promote better adherence to the recommendations. Patients were encouraged to place the leaflet in a visible location at home. The leaflet consisted of 5 main recommendations to improve vitamin D levels, each accompanied by a brief description. It was designed in warm colors evoking the action of the sun and was written in the first person to involve the patient in their habits and treatment.

These recommendations were:

"I'm going to go out and get some sunshine." We produce most of our vitamin D ourselves when we get sunshine.

"My bones will be stronger." Good levels of vitamin D make our bones more resistant, and they don't break easily.

"Physical exercise and sunshine." Going for a walk 4 times a week for about 20 minutes will make my muscle mass improve and increase my vitamin D.

"My diet also helps me." Oily fish (salmon, tuna, trout), eggs, avocado and mushrooms, among other foods, provide me with a lot of vitamin D.

"How do I take vitamin D?". If I am already taking a vitamin D supplement, I will take it with meals and at the same time to absorb it better.

An information sheet was also designed for PCPs, requesting their collaboration in the study. This included providing previous data on the patient's vitamin D and increasing the frequency of vitamin D determinations to once every 4 or 6 months, as suggested by the main international guides [4,29,30]. Accordingly, the analysis of serum vitamin D levels at the beginning of the study, at 4 months and at 8 months (end of the study) was requested through the physician referral form. This sheet was to be given to the PCP by the patient.

Study Population

Patients were invited to participate in the study when the pharmacist detected any potential symptoms associated with vitamin D deficiency, or when a patient came to the pharmacy with a first prescription of vitamin D supplement.

Patients with possible vitamin D deficiency were identified during the pharmacist's routine activities through different methods: 1. Information available from the Electronic Health Insurance Card during dispensing, or, in the absence of that, by detecting private health prescriptions or prescriptions from other mutual societies dispensed in each community pharmacy; 2. Detection of symptoms associated with vitamin D deficiency/insufficiency, following a conversation in which the patient reported such symptoms; 3. A conversation with the patient in which the pharmacist identified lifestyle habits compatible with vitamin D deficiency.

In the case of patients who had a possible vitamin D deficiency detected by the pharmacy, they were referred to the PCP for confirmation through serum vitamin D analysis and, if so, with a possible recommendation for supplementation. When they returned to pick up their medication, they were offered the service.

Patient inclusion criteria were: age over 14 years (to avoid relying on a legal representative to vouch for minors under the age of 14 and to avoid biased); signature of informed consent and authorization from a parent or guardian if applicable; diagnosis of vitamin D deficiency or insufficiency by the PCP; detection through the pharmacist of lifestyle habits and/or symptoms compatible with vitamin D deficiency or insufficiency; patients being treated with medications that interfere with the absorption and/or metabolism of vitamin D, including carbamazepine, cimetidine, cholestyramine, colestipol, thiazide diuretics, phenytoin, phenobarbital and valproate.

Patient exclusion criteria were: hepatic, biliary, renal or cardiac insufficiency; hypoparathyroidism; kidney stones; patients who do not speak, read, or write Spanish; caregivers or dependents of a patient with vitamin D deficiency; patients who do not wish to

complete the informed consent form; and those without a valid phone number or without a mobile messaging application (e.g., WhatsApp) installed on their phone.

The study population included patients regardless of the origin or medical indication of their vitamin D supplementation. This encompassed individual taking vitamin D through multivitamin preparations, self-medicating, or under physician-directed treatment. The aim was to reflect real-world diversity in supplementation practices and not to restrict inclusion to strictly defined “therapeutic adequacy” parameters.

Description of the first intervention

Interventions were tailored based on the patient's current use of vitamin D supplements:

1. Patients with the first vitamin D supplement prescription from PCP received a brief explanation of vitamin D's functions and sources, with emphasis on habits related to deficiency. The pharmacist also provided advice on improving absorption.

2. Patients not taking supplements were informed about vitamin D's functions, sources, and lifestyle factors linked to deficiency. Common deficiency symptoms were explained to facilitate self-assessment. Pharmacists recommended these patients vitamin D supplementation.

Each patient was given the informed consent, which they could complete in the community pharmacy’s counselling area or at home. They also received supporting material, with a strong recommendation to place the leaflet in a visible or frequently used area at home. Patients were informed that they would receive reminders and educational videos via the mobile messaging application, and that they would be contacted by phone after four and eight months to proceed with the next phase of the study.

Follow-Up intervention

From the time the initial interview (T0) was delivered, messages were programmed by artificial intelligence to be sent to each patient on the dates they were supposed to take vitamin D (daily, weekly, biweekly or monthly). The videos were sent on the 20th of each month. All these notifications were made through the WhatsApp application.

In addition to follow-up through the survey, patients were informed that if, at any time during their follow-up period, their PCP changed their vitamin D supplementation schedule, they could contact the pharmacist in charge by phone or through WhatsApp to adjust their reminders accordingly.

Four (T4) and eight (T8) months after enrolling in the study, the pharmacist in charge was responsible for contacting participants by telephone, in chronological order, to complete the second and last interviews.

Data Collection

All pharmacies were recruited in June 2023, and pharmacists were trained accordingly. A 6-month inclusion period was established, during which the pharmacist in charge was responsible for submitting completed surveys to the principal researcher on a monthly basis.

Outcome Variables

The outcome variables measured and assessed through the surveys included socio-demographic data, dietary sources of vitamin D, serum levels of vitamin D, the number and name of medications and pathologies, quality of life (measured using a VAS of self-perceived quality of life, extracted from the EQ-5D), the number of days of physical exercise, and adherence to vitamin D supplementation, defined as taking the supplement at the prescribed dose and frequency.

Data Analysis

Data was analyzed using the SPSS statistical package (V.26.0, SPSS). Descriptive analyses were performed, where categorical variables were described using percentages and numbers (counts). Continuous variables were described using means and standard deviations for normally distributed data, and medians for non-parametric variables. To compare categorical variables between the three time points (T0, T4, T8), the chi-square test or Fisher's exact test was used when appropriate. For continuous variables, paired *t* tests were applied to compare means between the three time points. To examine the relationship between continuous variables, Pearson or Spearman correlation coefficients were calculated. Additionally, to assess the association between lifestyle factors and adequate serum Vitamin D levels, univariate binary logistic regression was conducted. The significance level was set at $p < 0.05$.

Ethic Approval

This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Research Ethical Committee of the Granada Centre (0967N23).

Results

From the total sample of 242 patients, 13% (n = 32) dropped out of the study. 7 patients reached optimal vitamin D levels, leading their PCP to discontinue the medication.

Of the remaining 210 patients, 78.6% (n = 165) were women. The mean age was 58.40 ± 14.08 years, with 79.8% (n = 166) being over 45 years old. Additionally, 39.5% (n = 83) of the patients were retired, and 49.5% (n = 104) had university-level studies (Table 1).

Before the intervention, only 10.0% (n = 21) of patients had an adequate vitamin D level (greater than 30 ng/ml). This figure increased to 61.0% (n = 128) at month 4 and to 64.3% (n = 135) at month 8 following the pharmacist-led intervention, with a statistically significant

decrease in the insufficient level from 39.5% (n = 83) at baseline to 11.4% (n = 24) at the final intervention ($p < 0.001$) (Figure 2).

In parallel, a significant improvement in self-perceived quality of life was observed, with VAS scores rising from 68.73 ± 18.72 to 76.80 ± 18.85 out of 100 points—an increase of 8.07 points ($p < 0.001$) (Table 2).

The percentage of patients classified as overweight or obese did not change significantly (T0: 46.7% (n = 98); T4: 44.3% (n = 93); T8: 34.3% (n = 72); p = 0.599). However, adherence to vitamin D supplementation improved markedly, increasing from 24.3% (n = 51) of patients to 91.4% (n = 192) and 95.2% (n = 200) at months 4 and 8, respectively ($p < 0.001$).

BMI remained stable from baseline to the final follow-up (T0: 25.33 ± 4.21 kg/m^2; T8: 25.27 ± 4.12 kg/m^2; p = 0.943).Walking at least 30 minutes daily increased without reaching statistical significance (T0: 4.30 ± 2.49 days/week; T4: 4.47 ± 2.32 days/week; T8: 4.74 ± 2.42 days/week; p = 0.073), while hours of sport per week showed a significant rise (T0: 2.29 ± 0.284 hours/week; T4: 2.77 ± 3.17 hours/week; T8 3.34 ± 3.55 hours/week, $p = 0.001$) (Table 2).

Dietary habits, particularly the consumption of vitamin D-rich foods, showed minimal change post-intervention. Most patients maintained their usual diets, except for a slight increase in the consumption of vitamin D-fortified dairy products (4.7%; $p = 0.002$).

After the logistic regression analysis, significant correlations were found between serum level of vitamin D, female gender and high BMI with different variables.It was observed patient was higher level of serum vitamin D when walking more than 30 minutes every day ($r = 0.227$, $p = 0.009$), they ate more salmon and anchovies ($r = 0.283$, p = 0.006 and $r = 0.360$, $p < 0.001$, respectively) and increased their BMI ($r = 0.205$, $p = 0.047$). Women walked more than 30 minutes a week compared to men ($r = 0.153$, $p = 0.026$), consumed more salmon (r =

0.179. p = 0.009), and more sardines (r = 0.161, p = 0.019). Patients with higher BMI reported lower self-perceived quality of life (r = -0.287, p < 0.001), walked less (r = -0.139, p = 0.043), practiced fewer hours of sport (r = -0.185, p = 0.007), and consumed less avocado (r = -0.167, p = 0.015) (Table 3).

Incorrect vitamin D supplementation, such as taking it at suboptimal times (e.g., taking it in the morning with breakfast and fatty foods) was associated with higher risk of vitamin D deficiency (OR = 2.57; 95% CI = 1.00-6.62; p = 0.046) (Table 4).

Discussion

This study demonstrates that pharmacist-led interventions can significantly improve serum vitamin D levels and patient adherence to supplementation protocols. The intervention, focused on education and reminders regarding the correct intake of vitamin D, led to measurable improvements in vitamin D levels and, importantly, patient-reported quality of life.

One of the most notable findings from the study was the significant improvement in correct vitamin D intake, which increased from 24.1% to 91.5% after eight months of pharmacist-led intervention. This improvement was driven by two complementary mechanisms: first, regular reminders improved adherence by helping patients remember to take their supplement consistently; second, pharmacists emphasized the importance of taking vitamin D with a main meal rich in fat, enhancing its bioavailability. Both factors likely contributed to the observed increase in serum vitamin D levels, with the administration guidance playing a key physiological role, as co-ingestion with fat has been shown to significantly enhance vitamin D absorption [31,32].

Moreover, patients who did not follow these recommendations—either by forgetting doses or by failing to take the supplement with a fat-containing meal—had more than double the

likelihood of inadequate vitamin D levels. This underscores the dual importance of adherence and proper administration technique, reinforcing the pharmacist's role in optimizing therapeutic outcomes through both behavioral and educational support [33,34].

The significant improvement observed in patients' quality of life, as measured by a VAS, reinforces the relevance of the intervention beyond biochemical outcomes. From baseline to month 8, VAS scores increased by over 8 points (from 68.7 to 76.8, $p < 0.001$), suggesting a tangible perception of health improvement. These findings align with previous research indicating that vitamin D supplementation and improved adherence can positively influence well-being and general vitality. Although the study was not designed to establish causality, the consistency of improvements in both vitamin D serum levels and subjective quality of life suggests a beneficial association, potentially mediated by increased health awareness and patient activation following the pharmacist-led intervention. This also strengthens the rationale for including pharmacists in patient-centered preventive strategies. Importantly, these results address concerns regarding the emphasis placed on quality of life in the background, now supported by direct and statistically significant outcome data.

Dietary habits played a key role in improving vitamin D levels among participants. The increased consumption of vitamin D-rich foods, particularly mushrooms and anchovies, was associated with higher post-intervention vitamin D levels. This could reflect a complex interaction between dietary patterns or compensatory changes made by patients, suggesting that not all vitamin D-rich foods may have the same impact on vitamin D status[35]. This highlights the need for more precise dietary recommendations in future studies, tailored to individual dietary habits and preferences.

This study found a statistically significant improvement in self-perceived quality of life, with patients reporting an 8.07-point increase ($p < 0.001$). While this improvement coincided with

a rise in vitamin D levels, it is important to acknowledge that attributing this effect solely to biochemical correction is methodologically limited. Quality of life is a multifactorial outcome that may have been influenced by several confounding variables, including increased engagement with a healthcare professional, behavioral modifications (e.g., diet, physical activity), and the psychological impact of being monitored and supported.

Although previous studies have demonstrated a positive correlation between adequate vitamin D levels and improved quality of life—particularly among individuals with chronic conditions [36–39], the present study does not isolate vitamin D as the sole explanatory variable. The pharmacist's role likely contributed to multiple aspects of patient care, including education, adherence support, and overall health empowerment, which in themselves may enhance perceived well-being.

Therefore, while alternative strategies to increase vitamin D levels may be effective in biochemical terms, the added value of pharmacist-led interventions lies in their potential to address a broader range of determinants of health beyond supplementation alone. Future studies with controlled designs are needed to disentangle these overlapping effects.

Limitations and Future Directions

This study had several limitations. The primary limitation was the short duration of follow-up, which may not have been sufficient to observe changes. A longer study period, with vitamin D measurements every four months over a full year, would provide a more comprehensive understanding of the long-term impact of the intervention and help account for seasonal variations in vitamin D levels. Another limitation is the reliance on self-reported data, which may be affected by recall bias, social desirability bias, or interviewer bias, potentially compromising the accuracy of reported behaviors and outcomes. Finally, we acknowledge that no formal sample size calculation was conducted based on the pre-post intervention

design. This represents a methodological limitation that should be addressed in future studies aiming to assess intervention effects.

Looking ahead, the scalability of pharmacist-led interventions remains a challenge without political will and financial support. Expanding this model of care would require substantial investment, not only in financial resources but also in the training and recruitment of additional personnel. To implement this model on a larger scale, healthcare systems would need to invest in the education and certification of more pharmacists, ensuring they possess the necessary competencies to deliver high-quality interventions. Furthermore, coordination across healthcare sectors—such as primary care, hospitals, and community pharmacies—would be essential to facilitate the integration of pharmacists into existing care teams.

In the Spanish context, however, community pharmacies are often more focused on economic profitability than on social commitment, with limited incentives for pharmacists to broaden the scope of their practice. This lack of economic motivation provides a plausible explanation for the constraints on expanding the role of pharmaceutical care with the aim of improving public health and quality of life. This situation presents a significant barrier to scaling a more patient-centered model, as financial constraints and market-driven priorities frequently take precedence over broader health objectives. These factors necessitate both substantial investment in infrastructure and a clear commitment from policymakers to support the expansion of this model of care.

Conclusion

The study demonstrated that the correct intake of vitamin D, along with the modification of certain dietary habits due to pharmacists' interventions, significantly improved patients' vitamin D levels. A notable increase in perceived quality of life was also observed, although it cannot be determined whether this was directly attributable to the vitamin D levels, the pharmacist-led support, or other aspects of the intervention.

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Impact of Community Pharmacist-Led Interventions on Vitamin D Levels and Patient Quality of Life

Abstract

Background: The widespread deficiency of vitamin D is a recognized public health issue. Maintaining adequate levels of this vitamin is associated with a lower risk of bone fractures, and emerging evidence suggests its preventive role in various diseases.

Objective: This study aimed to investigate whether pharmacist-led intervention and follow-up can enhance patient adherence, improve vitamin D levels, and subsequently lead to an increase in perceived quality of life.

Methods: Multicenter quasi-experimental study with non-probabilistic sampling conducted in ten community pharmacies. Patients were recruited by pharmacists based on symptoms of vitamin D deficiency or current use of vitamin D supplements. Monthly follow-ups were conducted through electronic messaging. Eight months after enrollment, a follow-up survey was carried out via telephone. Outcome variables included socio-demographic data, vitamin D levels, self-perceived quality of life, and physical activity. Data analysis was conducted with a significance level set at $p < 0.05$.

Results: Among the 210 patients, the proportion adhering to the correct vitamin D intake significantly increased from 24.1% to 90.6% ($p < 0.001$) after eight months. Prior to the intervention, only 12.6% of patients had adequate vitamin D levels, which increased to 60.3% following pharmacist intervention (from 21.69 ± 9.32 to 33.13 ± 14.16 ng/mL, $p < 0.001$). Additionally, self-perceived quality of life scores improved from 68.73 ± 18.72 to 76.80 ± 18.85, $p < 0.001$), with 58.5% of patients reporting an improvementin their quality of life.

Conclusion: Pharmacist-led interventions significantly improved patient habits, resulting in increased vitamin D levels. These improvements were associated with a significant increase in patients' perceived quality of life.

Keywords: Vitamin D, Pharmaceutical Care, Community Pharmacy Services, Quality of Life, Public Health.

Key points

This study highlights the indispensable role of the pharmacist as a healthcare agent close and accessible to the patient. Pharmacists have contributed to patients' better understanding of their disease, actively involving them in their own treatment and transforming therapeutic success into a personal achievement.

Background

Vitamin D plays a crucial role in maintaining various aspects of health, particularly in bone metabolism, immune function, and overall well-being. Given its widespread deficiency, especially in older populations, adequate vitamin D levels are essential for preventing conditions such as osteoporosis, cardiovascular disease, and autoimmune disorders[1].

Historically, vitamin D has been associated with the regulation of bone metabolism.Adequate levels protect the geriatric patient by slowing down osteoporotic processes[1]. However, following the discovery of vitamin D receptors in many other systems, emerging evidence has linked vitamin D insufficiency to chronic conditions such as cardiovascular disease, diabetes, and certain immune-related disorders [2,3].

In Spain, the Spanish Society of Endocrinology and Nutrition (SEEN)[4] recommends maintaining serum vitamin D concentrations between 30 and 50 ng/ml. The World Medical Association and the Spanish Society for Bone and Mineral Metabolism Research have defined optimal plasma vitamin D levels as ≥30 ng/ml, insufficient levels as between 20 and 30 ng/ml, and deficient levels as below 20 ng/ml [4-6].

Controversy remains about whether the effects of vitamin D on non-bone-related systems are truly definitive[7-9]. This relationship can also be observed in patients considered healthy adults[10]. In this context, the role of the pharmacist becomes fundamental. Due to the variety of vitamin D dosages, ranging from 400IU to 50,000IU, with regimens that range from daily, weekly, biweekly, and even monthly doses, patients may become confused[11,12]. A study conducted in Spanish primary care involving 432 patients found that only 20% of those receiving vitamin D treatment had both a clinical indication and confirmed vitamin D deficiency—criteria used to define therapeutic adequacy in that context[13]. This underscores the frequent lack of alignment between prescribing practices and clinical guidelines.

Likewise, many patients do not correctly follow supplementation recommendations due to a lack of knowledge about vitamin D sources and variability in sun exposure[14].

Through targeted actions and activities, pharmacists can improve patient health in cooperation with doctors and other healthcare professionals, resulting in improved quality of life for patients[15-17]. Pharmacists also keep patients permanently informed about new updates related to their pathologies[18,19]. In the context of vitamin D deficiency, pharmacists can play a key role in informing patients about the implications of inadequate levels of this nutrient, particularly in relation to pathologies such as osteoporosis, osteomalacia, and musculoskeletal disorders, where vitamin D plays a well-established role in bone health and fracture prevention. In Spain, vitamin D supplements are available in various formulations with different dosing schedules, including daily, weekly, and monthly regimens. While extended dosing intervals are generally considered to improve adherence, some patients—particularly those who are asymptomatic or perceive vitamin D supplementation as non-essential—may still miss doses. This is especially relevant with monthly regimens, where the long interval between doses increases the chance of forgetfulness. In this context, pharmacists play a critical role in promoting adherence by providing tailored health education and emphasizing the importance of consistent vitamin D intake to prevent both skeletal and non-skeletal complications. These efforts support compliance with treatment guidelines, enhance clinical outcomes, and contribute to a more sustainable healthcare system and improved public health[20-23].

Objective

The aim of this study is to assess the impact of pharmacist's interventions on patient involvement in Vitamin D self-care, vitamin D levels and self-perceived quality of life.

Methods

Study Design

A multicenter, quasi-experimental study using non-probability convenience sampling design was conducted in ten Spanish community pharmacies (Granada and Madrid) across four urban and rural locations over an eight-month period during June 2023 and October 2024. The pharmacies that participated in the study were chosen based on the number of pharmacists working in them to be able to assume the provision of the service (n = 16). All the proposed pharmacies voluntarily agreed to participate, four pharmacies decided not to participantes due to circunstancial problems, and no response was obtained from two pharmacies. Pharmacies were sought in urban and rural locations and in two cities with central and southern locations to avoid bias.

The pharmacist received prior training based on the Spanish Society of Endocrinology and Nutrition criteria for screening patients with vitamin D deficiency/insufficiency, including information on the survey and variables that were considered in the study, the pharmacist's intervention and communication with the primary care physician (PCP) for referral with the request for vitamin D analysis and vitamin D supplementation[4].

Pharmacists identified potential beneficiary patients, offered them the monitoring service, and provided them with education using support materials and additional resources, and they were provided with the survey that was to be passed to them by the pharmacist by telephone at month, month 4 and month 8. Patients were informed that they would receive reminders on the days they were due to take vitamin D, as well as a short monthly video with a maximum duration of one and a half minutes, explaining some of the characteristics of vitamin D deficiency or insufficiency and the steps to take to improve vitamin D levels. Once month later, patients relieve the first phone call to the first interview through the survey. After four and eight months from the first interview (T0), the pharmacist conducted follow-up phone

113 consultations (second interview (T4) and last interview (T8)) with patients to evaluate any
114 changes in their condition. The survey used with each patient was exactly the same as in the
115 initial interview, except for the socio-health characteristics block, which was eliminated
116 (except for the patient's weight) to avoid duplication data.

117 ***Survey Design***

118 The survey had five different blocks: socio-health characteristics, physical activity, diet,
119 medication and perception of health status.The survey questions were taken from the 2020
120 version of the 'European Health Survey in Spain'[24], selecting the most relevant items to
121 understand patient habits that could contribute to vitamin D deficiency, especially the
122 modules on physical activity, nutrition and medication consumption (sections T, U and P
123 respectively). The last block included a visual analogue scale (VAS) of self-perceived quality
124 of life, extracted from the EuroQol-5D (EQ-5D) questionnaire[25]. The EQ-5D is a useful
125 instrument for application in primary care, valued for its quick and easy administration.

126 This survey was piloted with a sample of 49 patients[26] and subsequently reviewed by a
127 committee of fifteen experts specializing in various fields related to vitamin D, different from
128 the researchers. The committee consisted of six doctors (Primary Care, Endocrinology,
129 Urology, Rheumatology, and Internal Medicine), five professors from the Faculty of
130 Pharmacy (departments of Pharmacology, Pharmacy and Pharmaceutical Technology, and
131 Nutrition), three community pharmacists, and a physiotherapist. The audit was carried out
132 using the 'Delphi methodology'. In the dietary section, questions focused on the intake of
133 products rich in vitamin D, assessing whether an increase in intake could lead to higher
134 vitamin D levels and improved self-perceived quality of life.

135 The initial interview consisted of 25 questions, including five key areas: socio-demographic
136 characteristics (4 questions), physical activity (4 questions), diet (8 questions), medication (8

questions), and health status (1 question). It was designed for self-administration, using simple and concise language to allow patients to complete the survey at home or in the pharmacy, minimizing interviewer bias and ensuring the collection of data on serum vitamin D levels upon request through the PCP. After three rounds, during which the expert committee reached a consensus, the final version of the survey consisted of 27 questions. Once consensus was reached, the survey design was finalized.

A second and last interview was then designed at four (T4) and eight (T8) months to assess any changes in lifestyle, medication, or dietary habits and to determine whether these changes significantly impacted vitamin D levels and perception of health status. This survey repeated the same questions, with two additional items to assess whether patients had informed their PCP about their participation in the study, whether they received medication reminders correctly, and their evaluation of the videos. These items were positively evaluated by the expert committee.

Supporting Material

During the initial interviews, supplementary material was provided to support the pharmacist's intervention and promote better adherence to the recommendations. Patients were encouraged to place the leaflet in a visible location at home. The leaflet consisted of 5 main recommendations to improve vitamin D levels, each accompanied by a brief description. It was designed in warm colors evoking the action of the sun and was written in the first person to involve the patient in their habits and treatment.

These recommendations were:

"I'm going to go out and get some sunshine." We produce most of our vitamin D ourselves when we get sunshine.

160 “My bones will be stronger.” Good levels of vitamin D make our bones more resistant, and
161 they don't break easily.

162 “Physical exercise and sunshine.” Going for a walk 4 times a week for about 20 minutes will
163 make my muscle mass improve and increase my vitamin D.

164 “My diet also helps me.” Oily fish (salmon, tuna, trout), eggs, avocado and mushrooms,
165 among other foods, provide me with a lot of vitamin D.

166 “How do I take vitamin D?”. If I am already taking a vitamin D supplement, I will take it with
167 meals and at the same time to absorb it better.

168 An information sheet was also designed for PCPs, requesting their collaboration in the study.
169 This included providing previous data on the patient's vitamin D and increasing the frequency
170 of vitamin D determinations to once every 4 or 6 months, as suggested by the main
171 international guides [4,27,28]. Accordingly, the analysis of serum vitamin D levels at the
172 beginning of the study, at 4 months and at 8 months (end of the study) was requested through
173 the physician referral form. This sheet was to be given to the PCP by the patient.

174 ***Study Population***

175 Patients were invited to participate in the study when the pharmacist detected any potential
176 symptoms associated with vitamin D deficiency, or when a patient came to the pharmacy with
177 a first prescription of vitamin D supplement.

178 Patients with possible vitamin D deficiency were identified during the pharmacist's routine
179 activities through different methods: 1. Information available from the Electronic Health
180 Insurance Card during dispensing, or, in the absence of that, by detecting private health
181 prescriptions or prescriptions from other mutual societies dispensed in each community

pharmacy; 2. Detection of symptoms associated with vitamin D deficiency/insufficiency, following a conversation in which the patient reported such symptoms; 3. A conversation with the patient in which the pharmacist identified lifestyle habits compatible with vitamin D deficiency.

In the case of patients who had a possible vitamin D deficiency detected by the pharmacy, they were referred to the PCP for confirmation through serum vitamin D analysis and, if so, with a possible recommendation for supplementation. When they returned to pick up their medication, they were offered the service.

Patient inclusion criteria were: age over 14 years (to avoid relying on a legal representative to vouch for minors under the age of 14 and to avoid biased); signature of informed consent and authorization from a parent or guardian if applicable; diagnosis of vitamin D deficiency or insufficiency by the PCP; detection through the pharmacist of lifestyle habits and/or symptoms compatible with vitamin D deficiency or insufficiency; patients being treated with medications that interfere with the absorption and/or metabolism of vitamin D, including carbamazepine, cimetidine, cholestyramine, colestipol, thiazide diuretics, phenytoin, phenobarbital and valproate.

Patient exclusion criteria were: hepatic, biliary, renal or cardiac insufficiency; hypoparathyroidism; kidney stones; patients who do not speak, read, or write Spanish; caregivers or dependents of a patient with vitamin D deficiency; patients who do not wish to complete the informed consent form; and those without a valid phone number or without a mobile messaging application (e.g., WhatsApp) installed on their phone.

The study population included patients regardless of the origin or medical indication of their vitamin D supplementation. This encompassed individual taking vitamin D through multivitamin preparations, self-medicating, or under physician-directed treatment. The aim

was to reflect real-world diversity in supplementation practices and not to restrict inclusion to strictly defined “therapeutic adequacy” parameters.

Description of the first intervention

Interventions were tailored based on the patient's current use of vitamin D supplements:

1. Patients with the first vitamin D supplement prescription from PCP received a brief explanation of vitamin D's functions and sources, with emphasis on habits related to deficiency. The pharmacist also provided advice on improving absorption.

2. Patients not taking supplements were informed about vitamin D's functions, sources, and lifestyle factors linked to deficiency. Common deficiency symptoms were explained to facilitate self-assessment. Pharmacists recommended these patients vitamin D supplementation.

Each patient was given the informed consent, which they could complete in the community pharmacy’s counselling area or at home. They also received supporting material, with a strong recommendation to place the leaflet in a visible or frequently used area at home. Patients were informed that they would receive reminders and educational videos via the mobile messaging application, and that they would be contacted by phone after four and eight months to proceed with the next phase of the study.

Follow-Up intervention

From the time the initial interview (T0) was delivered, messages were programmed by artificial intelligence to be sent to each patient on the dates they were supposed to take vitamin D (daily, weekly, biweekly or monthly). The videos were sent on the 20th of each month. All these notifications were made through the WhatsApp application.

In addition to follow-up through the survey, patients were informed that if, at any time during their follow-up period, their PCP changed their vitamin D supplementation schedule, they could contact the pharmacist in charge by phone or through WhatsApp to adjust their reminders accordingly, or in case of withdrawal of the supplementation prescription remove the reminder. In the latter case they were asked if they wanted to continue receiving the monthly video.

Four (T4) and eight (T8) months after enrolling in the study, the pharmacist in charge was responsible for contacting participants by telephone, in chronological order, to complete the second and last interviews.

Data Collection

All pharmacies were recruited in June 2023, and pharmacists were trained accordingly. A 6-month inclusion period was established, during which the pharmacist in charge was responsible for submitting completed surveys to the principal researcher on a monthly basis.

Outcome Variables

The outcome variables measured and assessed through the surveys included socio-demographic data, dietary sources of vitamin D, serum levels of vitamin D, the number and name of medications and pathologies, quality of life (measured using a VAS of self-perceived quality of life, extracted from the EQ-5D), the number of days of physical exercise, and adherence to vitamin D supplementation, defined as taking the supplement at the prescribed dose and frequency.

Data Analysis

Data was analyzed using the SPSS statistical package (V.26.0, SPSS). Descriptive analyses were performed, where categorical variables were described using percentages and numbers

(counts). Continuous variables were described using means and standard deviations for normally distributed data, and medians for non-parametric variables. To compare categorical variables between the three time points (T0, T4, T8), the chi-square test or Fisher's exact test was used when appropriate. For continuous variables, paired t-tests were applied to compare means between the three time points. Additionally, to assess the association between lifestyle factors and adequate serum Vitamin D levels, univariate binary logistic regression was conducted. The significance level was set at $p < 0.05$.

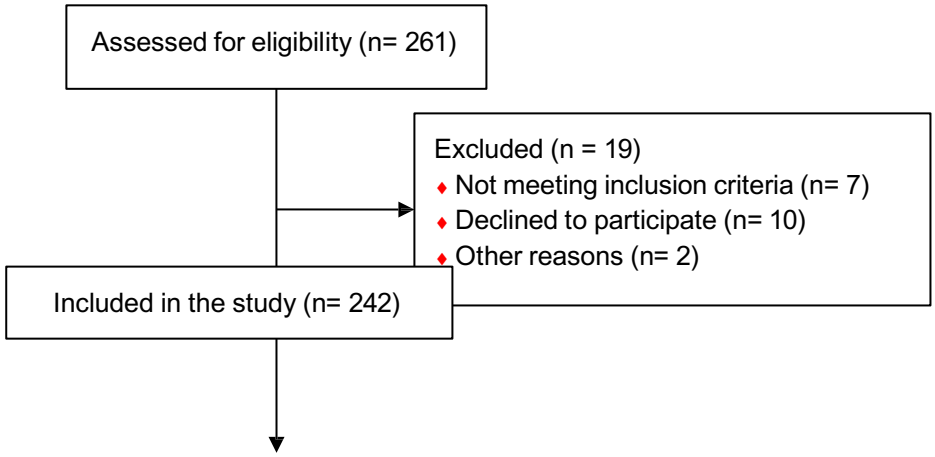
Ethic Approval

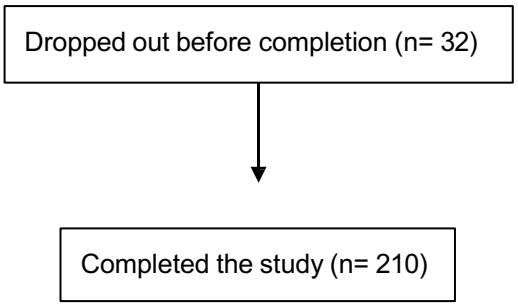
This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Research Ethical Committee of the Granada Centre (0967N23).

Results

From the total sample of 242 patients, 13% (n = 32) dropped out of the study. 7 patients of those included in the study, reached optimal vitamin D levels during the 8 months, which led their PCP to discontinue the medication, and therefore did not continue with the interviews.

Figure 2. Flow diagram of the participants in this study.





Of the remaining 210 patients, 78.6% (n = 165) were women. The mean age was 58.40 ± 14.08 years, with 79.8% (n = 166) being over 45 years old. Additionally, 39.5% (n = 83) of the patients were retired, and 49.5% (n = 104) had university-level studies (Table 1). Of the most frequent pathologies suffered by the study population, diabetes was found in 10. 9 % of patients (n = 22), asthma or COPD in 7.9 % (n = 16), autoimmune disease in 7.4 % (n = 15), hypercholestermonin in 29.2 % (n = 59), hypertension in 46.6 % (n = 96) of patients, hyper or hypothyroidism in 9.5 % (n = 19), osteoporosis in 11.9 % (n = 24), depression in 12.9 % (n = 26), insomnia in 26.1 % (n = 55), and only 15.2 % (n = 32) had no diagnosed pathology. The most frequent group of drugs that could affect vitamin D levels were statins in 29.9 % (n = 63) of patients, diuretics in 10.9 % (n = 23) and corticosteroid in 4.3 % (n = 9) (Table 1).

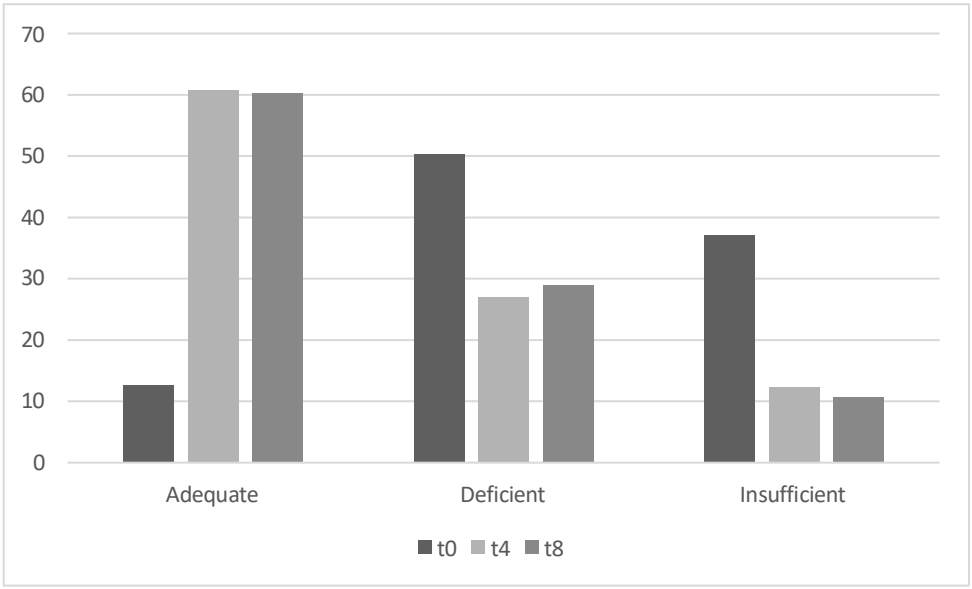
Table 1. Sociodemographic characteristics of the study sample.

	N (%)
Gender (Female)	165 (77.8)
Over 45 years	166 (79.8)
Employment status (Retired)	83 (39.2)
Diabetes	22 (10.9)
Asthma/COPD	16 (7.9)
Autoimmune disease	15 (7.4)
Hypercholesterolemia	59 (29.2)
Hypertension	96 (46.6)

Hyper/hypothyroidism	19 (9.5)
Osteoporosis	24 (11.9)
Depression	26 (12.9)
Insomnia	55 (26.1)
No pathologies	32 (15.2)
Statin	63 (29,9)
Diuretic	23 (10,9)
Corticosteroid	9 (4,3)

Before the intervention, only 10.0% (n = 21) of patients had an adequate vitamin D level (greater than 30 ng/ml). This figure increased to 61.0% (n = 128) at month 4 and to 64.3% (n = 135) at month 8 following the pharmacist-led intervention, with a statistically significant decrease in the insufficient level from 39.5% (n = 83) at baseline to 11.4% (n = 24) at the final intervention ($p < 0.001$) (Figure 2).

Figure 2. Level of vitamin D before and after intervention.



In parallel, a significant improvement in self-perceived quality of life was observed, with VAS scores rising from 68.73 ± 18.72 to 76.80 ± 18.85 out of 100 points—an increase of 8.07 points ($p < 0.001$) (Table 2).

The percentage of patients classified as overweight or obese did not change significantly (T0: 46.7% (n = 98); T4: 44.3% (n = 93); T8: 34.3% (n = 72); p = 0.599). However, adherence to vitamin D supplementation improved markedly, increasing from 24.3% (n = 51) of patients to 91.4% (n = 192) and 95.2% (n = 200) at months 4 and 8, respectively ($p < 0.001$).

BMI remained stable from baseline to the final follow-up (T0: 25.33 ± 4.21 kg/m^2; T8: 25.27 ± 4.12 kg/m^2; p = 0.943).Walking at least 30 minutes daily increased without reaching statistical significance (T0: 4.30 ± 2.49 days/week; T4: 4.47 ± 2.32 days/week; T8: 4.74 ± 2.42 days/week; p = 0.073), while hours of sport per week showed a significant rise (T0: 2.29 ± 0.284 hours/week; T4: 2.77 ± 3.17 hours/week; T8 3.34 ± 3.55 hours/week, p = 0.001) (Table 2).

Table 2. Variables measured pre- and post-intervention.

Categorical variables N (%)				
	T0	T4	T8	p-value
Overweight/obesity	98 (46.2)	93 (43.9)	72 (32.1)	0.599
Adherence	51 (24.1)	192 (90.6)	205 (91.5)	**<0.001**
Intense physicalactivity	89 (42.0)	94 (44.3)	127 (56.7)	0.077
Continuous variables (Mean ± SD)				
	T0	T4	T8	p-value
BMI	25.33 ± 4.21	25.36 ± 4.10	25.27 ± 4.12	0.943
Walking ≥ 30 min (days/week)	4.30 ± 2.49	4.47 ± 2.32	4.74 ± 2.42	0.073
Hours of sport per week	2.29 ± 0.284	2.77 ± 3.17	3.34 ± 3.55	**0.001**
Vitamin D serum level (ng/mL)	21.69 ± 9.33	30.42 ± 10.15	33.13 ± 14.16	**<0.001**

Quality of life (VAS, 0 – 100)	68.73 ± 18.72	74.70 ± 17.98	76.80 ± 18.85	**<0.001**

*Statistical comparisons were performed using the chi-square test for categorical variables and the paired t-test for continuous variables.

BMI: Body Mass Index;

Vit D: Vitamin D

VAS: Visual Analogical Scale

Incorrect vitamin D supplementation, such as taking it at suboptimal times (e.g., taking it in the morning with breakfast and fatty foods) was associated with higher risk of vitamin D deficiency (OR = 2.57; 95% CI = 1.00-6.62; p = 0.046) (Table 3).

Table 3. Association between lifestyle factors and adequate serum Vitamin D levels (≥ 30 ng/mL).

Adequate Vit D	OR	95%CI	p-value
Age	0.73	0.45-1.11	0.491
Gender (female)	1.43	0.61-3.40	0.273
Correct intake of Vit D	2.57	**1.00-6.62**	**0.046**
BMI	1.69	0.74-3.90	0.150
Walking at least 30 min	3.88	0.72-20.94	0.102
Hour of daily sport	1.80	0.80-4.05	0.112
Avocado intake	1.38	0.60-3.18	0.290
Egg intake	0.71	0.06-8.01	0.631
Salmon intake	1.28	0.59-2.76	0.333
Tuna intake	1.48	0.40-5.43	0.396
Mushroom intake	3.01	**1.16-7.85**	**0.013**
Anchovies intake	2.33	**1.06-5.11**	**0.026**
Sardine intake	0.86	0.40-1.85	0.420
Supplemented dairy intake	1.48	0.61-3.58	0.260

Statin consumption	0.28	**0.05-0.49**	**0.020**
Quality of life	1.02	0.99-1.04	0.070

All p-values and ORs were obtained using univariate binary logistic regression. Statistically significant associations ($p < 0.05$).

Vit D: Vitamin D

Discussion

This study demonstrates that pharmacist-led interventions can significantly improve serum vitamin D levels and patient adherence to supplementation protocols. The intervention, focused on education and reminders regarding the correct intake of vitamin D, led to measurable improvements in vitamin D levels and, importantly, patient-reported quality of life.

One of the most notable findings from the study was the significant improvement in correct vitamin D intake, which increased from 24.1% to 91.5% after eight months of pharmacist-led intervention. This improvement was driven by two complementary mechanisms: first, regular reminders improved adherence by helping patients remember to take their supplement consistently; second, pharmacists emphasized the importance of taking vitamin D with a main meal rich in fat, enhancing its bioavailability. Both factors likely contributed to the observed increase in serum vitamin D levels, with the administration guidance playing a key physiological role, as co-ingestion with fat has been shown to significantly enhance vitamin D absorption [29,30].

Moreover, patients who did not follow these recommendations—either by forgetting doses or by failing to take the supplement with a fat-containing meal—had more than double the likelihood of inadequate vitamin D levels. This underscores the dual importance of adherence and proper administration technique, reinforcing the pharmacist's role in optimizing therapeutic outcomes through both behavioral and educational support [31,32].

The significant improvement observed in patients' quality of life, as measured by a VAS, reinforces the relevance of the intervention beyond biochemical outcomes. From baseline to month 8, VAS scores increased by over 8 points, suggesting a tangible perception of health improvement. These findings align with previous research indicating that vitamin D supplementation and improved adherence can positively influence well-being and general vitality. Although the study was not designed to establish causality, the consistency of improvements in both vitamin D serum levels and subjective quality of life suggests a beneficial association, potentially mediated by increased health awareness and patient activation following the pharmacist-led intervention. This also strengthens the rationale for including pharmacists in patient-centered preventive strategies. Importantly, these results address concerns regarding the emphasis placed on quality of life in the background, now supported by direct and statistically significant outcome data.

Dietary habits played a key role in improving vitamin D levels among participants. The increased consumption of vitamin D-rich foods, particularly mushrooms and anchovies, was associated with higher post-intervention vitamin D levels. This could reflect a complex interaction between dietary patterns or compensatory changes made by patients, suggesting that not all vitamin D-rich foods may have the same impact on vitamin D status[33]. This highlights the need for more precise dietary recommendations in future studies, tailored to individual dietary habits and preferences.

This study found a statistically significant improvement in self-perceived quality of life, with patients reporting an 8.07-point increase ($p < 0.001$). While this improvement coincided with a rise in vitamin D levels, it is important to acknowledge that attributing this effect solely to biochemical correction is methodologically limited. Quality of life is a multifactorial outcome that may have been influenced by several confounding variables, including increased

engagement with a healthcare professional, behavioral modifications (e.g., diet, physical activity), and the psychological impact of being monitored and supported.

Although previous studies have demonstrated a positive correlation between adequate vitamin D levels and improved quality of life—particularly among individuals with chronic conditions [34-37], the present study does not isolate vitamin D as the sole explanatory variable. The pharmacist's role likely contributed to multiple aspects of patient care, including education, adherence support, and overall health empowerment, which in themselves may enhance perceived well-being.

Therefore, while alternative strategies to increase vitamin D levels may be effective in biochemical terms, the added value of pharmacist-led interventions lies in their potential to address a broader range of determinants of health beyond supplementation alone. Future studies with controlled designs are needed to disentangle these overlapping effects.

Limitations and Future Directions

This study had several limitations. The primary limitation was the short duration of follow-up, which may not have been sufficient to observe changes. A longer study period, with vitamin D measurements every four months over a full year, would provide a more comprehensive understanding of the long-term impact of the intervention and help account for seasonal variations in vitamin D levels. Another limitation is the reliance on self-reported data, which may be affected by recall bias, social desirability bias, or interviewer bias, potentially compromising the accuracy of reported behaviors and outcomes. Finally, we acknowledge that no formal sample size calculation was conducted based on the pre-post intervention design. This represents a methodological limitation that should be addressed in future studies aiming to assess intervention effects.

Looking ahead, the scalability of pharmacist-led interventions remains a challenge without political will and financial support. Expanding this model of care would require substantial investment, not only in financial resources but also in the training and recruitment of additional personnel. To implement this model on a larger scale, healthcare systems would need to invest in the education and certification of more pharmacists, ensuring they possess the necessary competencies to deliver high-quality interventions. Furthermore, coordination across healthcare sectors—such as primary care, hospitals, and community pharmacies—would be essential to facilitate the integration of pharmacists into existing care teams.

In the Spanish context, however, community pharmacies are often more focused on economic profitability than on social commitment, with limited incentives for pharmacists to broaden the scope of their practice. This lack of economic motivation provides a plausible explanation for the constraints on expanding the role of pharmaceutical care with the aim of improving public health and quality of life. This situation presents a significant barrier to scaling a more patient-centered model, as financial constraints and market-driven priorities frequently take precedence over broader health objectives. These factors necessitate both substantial investment in infrastructure and a clear commitment from policymakers to support the expansion of this model of care.

Conclusion

The study demonstrated that the correct intake of vitamin D, along with the modification of certain dietary habits due to pharmacists' interventions, significantly improved patients' vitamin D levels. A notable increase in perceived quality of life was also observed, although it cannot be determined whether this was directly attributable to the vitamin D levels, the pharmacist-led support, or other aspects of the intervention.

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Impact of Community Pharmacist-Led Interventions on Vitamin D Levels and Patient Quality of Life

FIGURE LEGENDS

Figure 1. Flow diagram of the participants in this study.

Figure 2. Level of vitamin D before and after intervention.

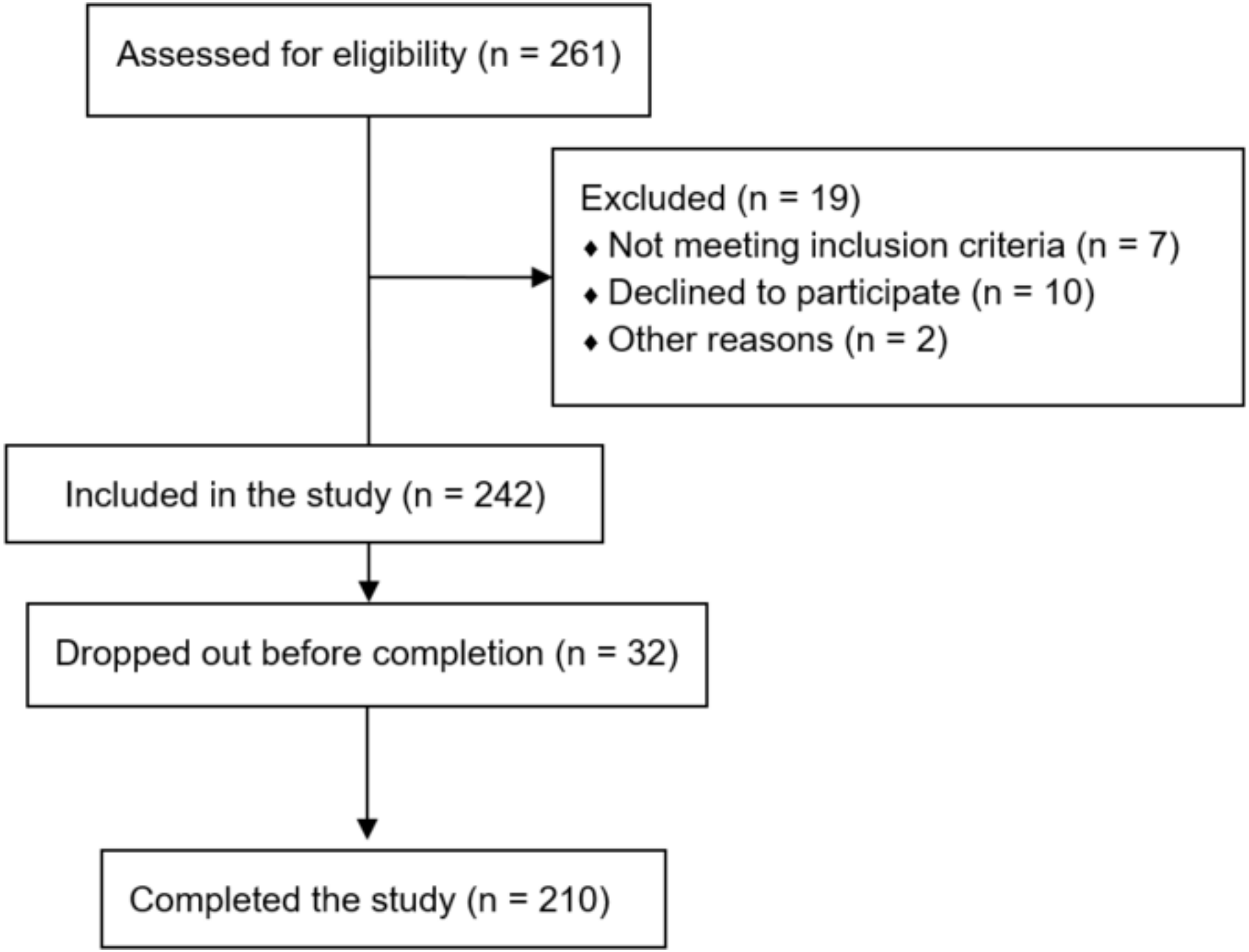

Figure 2

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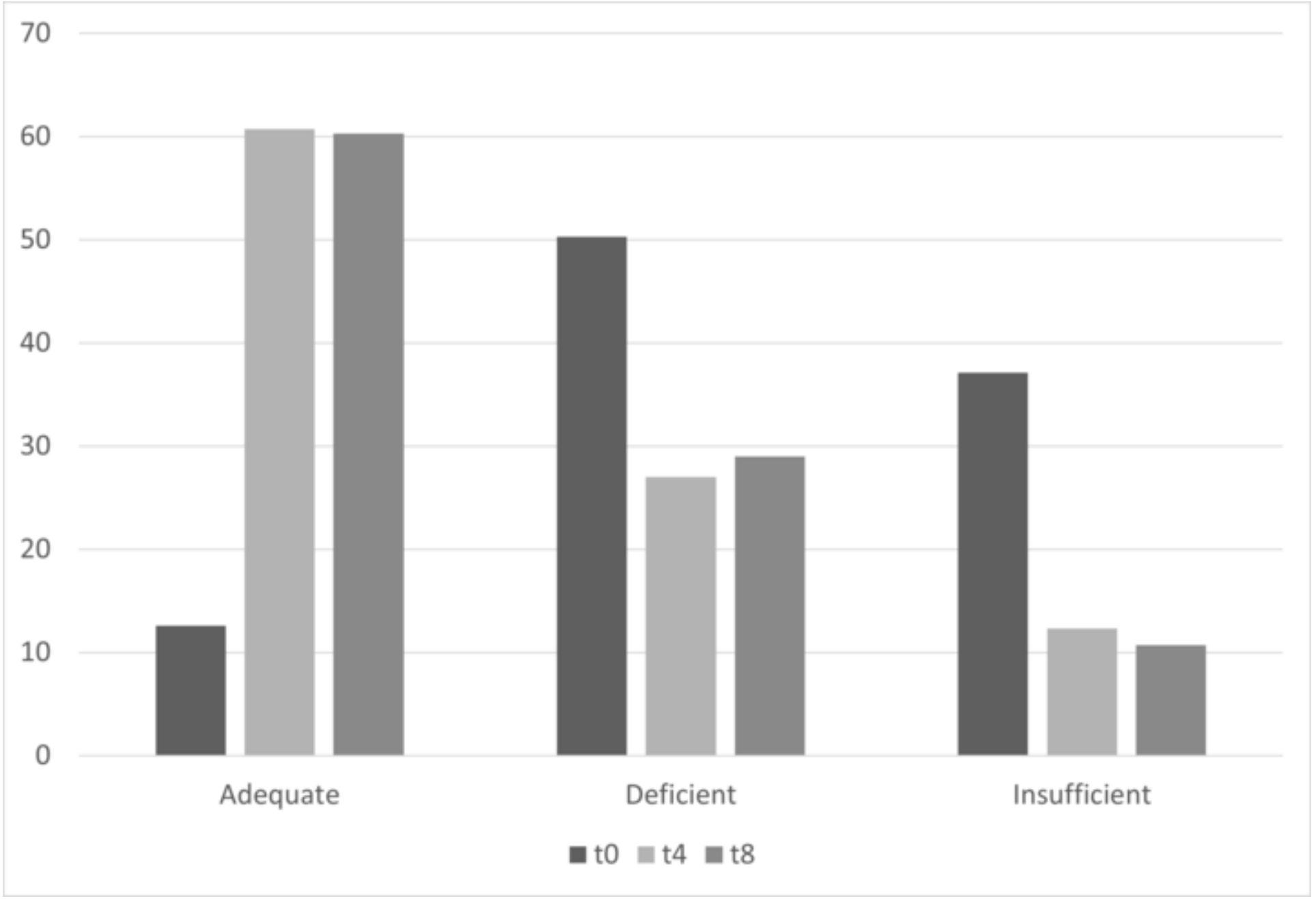

Impact of Community Pharmacist-Led Interventions on Vitamin D Levels and Patient Quality of Life

TABLES

Table 1. Sociodemographic characteristics of the study sample.

	N (%)
Gender (Female)	165 (77.8)
Over 45 years	166 (79.8)
Employment status (Retired)	83 (39.2)
Level of studies (University)	105 (49.5)
Diabetes	22 (10.9)
Asthma/COPD	16 (7.9)
Autoimmune disease	15 (7.4)
Hypercholesterolemia	59 (29.2)
Hypertension	96 (46.6)
Hyper/hypothyroidism	19 (9.5)
Osteoporosis	24 (11.9)
Depression	26 (12.9)
Insomnia	55 (26.1)
No pathologies	32 (15.2)
Statin	63 (29,86)
Diuretic	23 (10,90)
Corticosteroid	9 (4,27)

Table 2. Variables measured pre- and post-intervention.

Categorical variables N (%)				
	T0	T4	T8	*p* value
Overweight/obesity	98 (46.2)	93 (43.9)	72 (32.1)	0.599
Adherence	51 (24.1)	192 (90.6)	205 (91.5)	**< 0.001**
Intense physical activity	89 (42.0)	94 (44.3)	127 (56.7)	0.077
Continuous variables (Mean ± SD)				
	T0	T4	T8	*p* value
BMI	25.33 ± 4.21	25.36 ± 4.10	25.27 ± 4.12	0.943
Walking ≥ 30 min (days/week)	4.30 ± 2.49	4.47 ± 2.32	4.74 ± 2.42	0.073
Hours of sport per week	2.29 ± 0.284	2.77 ± 3.17	3.34 ± 3.55	**0.001**
Vitamin D serum level (ng/mL)	21.69 ± 9.33	30.42 ± 10.15	33.13 ± 14.16	**< 0.001**
Quality of life (VAS, 0–100)	68.73 ± 18.72	74.70 ± 17.98	76.80 ± 18.85	**< 0.001**

*Statistical comparisons were performed using the chi-square test for categorical variables and the paired *t* test for continuous variables.

BMI: Body Mass Index;

Vit D: Vitamin D

VAS: Visual Analogical Scale

Table 3. Pearson correlation coefficients between serum Vitamin D levels, female sex, and BMI with selected variables.

Correlated variable	Outcome variable	*r* (Pearson)	*p* value
Serum Vitamin D level	Walking ≥ 30 min/day	0.227	0.009
	Consumption of salmon	0.283	0.006
	Consumption of anchovies	0.360	< 0.001
	BMI increase	0.205	0.047
Female sex	Walking ≥ 30 min/day	0.153	0.026
	Consumption of salmon	0.179	0.009
	Consumption of sardines	0.161	0.019
BMI	Quality of life (VAS)	-0.287	< 0.001
	Walking ≥ 30 min/day	-0.139	0.043
	Sport practice (hours/week)	-0.185	0.007
	Avocado intake	-0.167	0.015

r: Pearson correlation coefficient. Statistical significance set at $p < 0.05$.

VAS: Visual Analogue Scale

BMI: Body Mass Index

Table 4. Association between lifestyle factors and adequate serum Vitamin D levels (≥30 ng/mL).

Adequate Vit D	OR	95% CI	*p* value
Age	0.73	0.45-1.11	0.491
Gender (female)	1.43	0.61-3.40	0.273
Correct intake of Vit D	2.57	**1.00-6.62**	**0.046**
BMI	1.69	0.74-3.90	0.150
Walking at least 30 min	3.88	0.72-20.94	0.102
Hour of daily sport	1.80	0.80-4.05	0.112
Avocado intake	1.38	0.60-3.18	0.290
Egg intake	0.71	0.06-8.01	0.631
Salmon intake	1.28	0.59-2.76	0.333
Tuna intake	1.48	0.40-5.43	0.396
Mushroom intake	3.01	**1.16-7.85**	**0.013**
Anchovies intake	2.33	**1.06-5.11**	**0.026**
Sardine intake	0.86	0.40-1.85	0.420
Supplemented dairy intake	1.48	0.61-3.58	0.260
Statin consumption	0.28	**0.05-0.49**	**0.020**
Quality of life	1.02	0.99-1.04	0.070

All *p* values and ORs were obtained using univariate binary logistic regression. Statistically significant associations ($p < 0.05$).

Vit D: Vitamin D

CRediT system

Conceptualization and Project administration: Lopez-Carmona F and Zarzuelo MJ; Methodology: Lopez-Carmona F and Toro-Ruiz A; Validation: Gomez-Guzman M; Formal analysis and Data Curation: Zarzuelo MJ and Piquer-Martinez C; Investigation: Lopez-Carmona F, Toro-Ruiz A and Zarzuelo MJ; Resources: Lopez-Carmona F; Writing - Original Draft: Lopez-Carmona F, Toro-Ruiz A, Ferreira-Alfaya FJ, Piquer-Martinez C, Gomez-Guzman and Zarzuelo MJ; Writing - Review & Editing: Valverde-Merino MI and Zarzuelo MJ; Visualization: Lopez-Carmona F, Toro-Ruiz A, Ferreira-Alfaya FJ, Piquer-Martinez C, Gomez-Guzman and Zarzuelo MJ; Supervision: Zarzuelo MJ.