Article

What Do People Know and Believe about Vitamin D?

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Abstract: People have been exposed to a lot of information regarding vitamin D, with evidence suggesting that vitamin D may be involved in numerous health conditions, subsequently creating concerns about vitamin D insufficiency. As a result, what do people really know or believe about this topic? In this cross-sectional study, we assessed vitamin D-related knowledge and beliefs in 59,273 French adults (NutriNet-Santé cohort) using a specific questionnaire. Answers to this questionnaire were weighted according to the French sociodemographic distribution and compared across individual characteristics, using $\chi^2$-tests. Physicians and media were identified as key information providers. Participants did not always accurately cite vitamin D sources (e.g., 72% only for sun exposure, fatty fish: 61%) or established health effects (e.g., bone health: 62%–78%). Conversely, they mentioned incorrect sources and health effects for which there is no consensus yet (e.g., skin cancer). These findings were modulated by age/generational and socioeconomic factors. A strong inconsistency was also observed between participants’ true vitamin D status (plasma 25-hydroxyvitamin D concentration) and their opinion about it. This study, the first in Europe with such a large sample, stresses the need for simple and up-to-date supports of communication for the public and healthcare professionals regarding sources and health effects of vitamin D.

Keywords: vitamin D; knowledge; population-based study; vitamin D status; beliefs

1. Introduction

What do people know or think they know about vitamin D? Recently, a lot of attention has been given to vitamin D (VitD). VitD has been known for a long time in the scientific community for its involvement in calcium homeostasis and bone health but the discovery that a vast majority of tissues are responsive to this molecule led to the possibility that VitD may play a key role in numerous health
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conditions. VitD is synthesized endogenously following skin exposure to the sun (UVB, 290–315 nm) and may also be provided by dietary sources, drugs and supplements [1–3].

With the increasing indoor lifestyle in developed countries, VitD insufficiency (VitD status <20 ng/mL [4,5]) has become a great public health concern since its prevalence in the general population is quite high: 42.5% in France [6], around 35%–70% in Europe [7] and 36% in the US [2]. Numerous studies of different types (e.g., ecological, observational, interventional, mechanistic) have been carried out regarding VitD (30,000+ hits on Pubmed for the last decade) and its involvement in multiple health outcomes, with very promising results [1,2,8–14]. As an illustration, a recent “umbrella review” [15] identified 137 health outcomes covered by systematic literature reviews (n = 107) and meta-analyses of observational studies (n = 74) and of randomized controlled trials (n = 87). In this review, discrepancies were observed between results from observational studies suggesting beneficial roles of VitD in several health outcomes (e.g., cancers, cardiovascular outcomes, cognitive disorders, infections, metabolic disorders, pregnancy/neonatal-related outcomes, dental caries, mortality) and inconclusive results from randomized controlled trials. In general, discrepancies between studies of different or same types have led to a lack of clear consensus within the scientific community on the role of VitD in health. Consensus knowledge seems to include the “classic” roles of VitD in bone health and other physiological roles (e.g., calcium homeostasis, cell division, immune system/inflammation, dentition and bone-related outcomes) [4,16,17]. Further studies and expertise works are needed to better elucidate the role of VitD in the prevention of non-skeletal chronic diseases.

In contrast, Caulfield et al. [18] recently showed that, in the media, VitD has mostly been considered as a “miracle vitamin” and associated with a wide variety of health outcomes, regardless of the actual scientific consensus.

People are exposed to a lot of information from several sources, thus, one may wonder what they really know about VitD and how they understand its role in health. Such information would be of interest for practitioners and public health institutions to improve the communication regarding VitD. Previous studies performed in several countries (mostly targeting specific groups) showed that VitD-related knowledge was limited [19–36]. To our knowledge, no study was performed in a large European sample from the general population and few linked VitD-related knowledge to various individual characteristics (including measured VitD status).

Thus, the objective of the present work was to assess several aspects of VitD-related knowledge (VitD sources, health effects, source of information . . . ) in ca. 60,000 French adults, across a wide range of individual characteristics.

2. Materials and Methods

2.1. Study Population

The NutriNet-Santé study is a large ongoing web-based cohort that was launched in France in 2009, focusing on the associations between nutrition and health. Involved participants are aged 18+ with Internet access who were recruited from the general population [37]. All questionnaires were completed online using a dedicated website (www.etude-nutrinet-sante.fr). The NutriNet-Santé study is conducted according to the Declaration of Helsinki guidelines and was approved by the Institutional Review Board of the French Institute for Health and Medical Research (IRB Inserm No. 0000388FWA00005831) and the “Commission Nationale de l’Informatique et des Libertés” (CNIL No. 908450/No. 909216). Electronic informed consent was obtained from each participant (EudraCT No. 2013-000929-31).

2.2. Data Collection

At baseline and each year thereafter, participants completed five questionnaires on sociodemographic and lifestyle characteristics, anthropometrics, dietary intake, physical activity, and health status. Drugs and/or dietary supplement use (including those containing VitD) was assessed in a
detailed questionnaire two months after baseline and in all yearly health questionnaires. As described elsewhere [38], a detailed questionnaire collected information on usual sun exposure and Fitzpatrick phototype, and VitD status (total 25-hydroxyvitamin D concentration) was measured for 860 participants.

A specific questionnaire was sent to all participants starting May 2012 to assess their VitD-related knowledge. Participants were asked if they had ever heard of VitD, what their sources of information are, what the sources of VitD are, what the health effects of VitD are and whether they thought that their VitD status was too low (complete questionnaire in Table S1).

2.3. Statistical Analyses

Data were weighted in order to obtain a representative sample of the French population in terms of sociodemographic distribution. Sex-specific normalized weighting was calculated using the SAS macro %CALMAR and the 2009 national Census INSEE data [39] on age, educational level, area of residence, occupational category, marital status and presence of children in the household.

Answers to the VitD questionnaire (N, %) were compared ($\chi^2$ tests) according to sociodemographic characteristics (sex, age, educational level, monthly income per household unit, living area (northern or southern France), size of the urban unit), VitD supplement/drug use, sources of information regarding VitD, VitD status, declared sun exposure and Fitzpatrick phototype. For all analyses (except those for the comparison according to age and sex), unconditional logistic regression models adjusted for age and sex were used.

Given the size of the study sample, even small differences were found to be of statistical significance. Therefore, for interpretation purposes, we considered inter-group differences $\geq$5%. $p$-value < 0.05 was considered statistically significant. All tests were two-sided. Analyses were carried out with SAS 9.3 (SAS Institute Inc., Cary, NC, USA).

3. Results

A total of 116,018 participants received the non-mandatory VitD questionnaire online by January 2015. Of these contacted people, 60,825 answered (response rate: 52%). There were 1552 participants excluded because of missing/unsuitable data in variables used for statistical weighting, leaving 59,273 participants for analyses. Individual characteristics’ distribution in our population (before and after weighting) is shown in Table 1.

3.1. Vitamin D (VitD) Knowledge and Sources of Information (Table 2, Table S2)

Overall, 92% of participants declared that they had already heard of VitD. This proportion was higher in women and older participants, as well as in those with a higher educational level and higher monthly income.

Main sources of information were physicians (41%), television (39%) and magazines (39%). Physicians were cited more often by women, older participants and those with a lower educational level. The media were cited more often by men, and a distinction was observed between television (more cited by younger individuals and those with lower education or income) and newspapers and radio (more cited by older subjects and those with higher income). School/university was more frequently quoted by younger, better-educated subjects and those with higher income.

3.2. Opinion Regarding VitD Status

Of the participants, 24% were concerned that their VitD status may be too low (Table 2). This proportion was higher in women, in participants living in northern France (25% vs. 19% in southern France, $p < 0.0001$, not tabulated), in urban communities, (28% vs. 20% in rural communities, $p < 0.0001$, not tabulated) and in those reporting (very) low sun exposure (27% vs. 19% for high sun exposure, $p < 0.0001$, not tabulated). This proportion reached 47% in those who had ever taken VitD supplements/drugs. Participants with fair skin (phototype I/II) were more concerned regarding their VitD status than those with a darker skin (phototype V/VI, 30% vs. 17%, $p < 0.0001$, not tabulated).
Table 1. Characteristics of the study population before and after statistical weighting, NutriNet-Santé cohort, 2009–2015.

| Unweighted | Weighted |
|------------|----------|
| N          | %        | N          | %        |
| Sex        |          |            |          |
| Men        | 13,237   | 22.3       | 26,834    | 46.7     |
| Women      | 46,036   | 77.7       | 30,675    | 53.3     |
| Age, years |          |            |          |
| Mean, SD   | 48.5     | 14.5       | 48.3      | 15.9     |
| <35        | 13,625   | 23.0       | 14,747    | 25.6     |
| 35–55      | 22,920   | 38.7       | 21,226    | 36.9     |
| ≥55        | 22,728   | 38.3       | 21,536    | 37.5     |
| Educational level | | | | |
| <high-school degree | 11,308 | 19.1 | 33,589 | 58.4 |
| <2 years after high-school degree | 8937 | 15.1 | 9164 | 15.9 |
| ≥2 years after high-school degree | 39,028 | 65.8 | 14,755 | 25.7 |
| Monthly income per household unit | | | | |
| <1,200€    | 8445     | 14.3       | 15,434    | 26.8     |
| 1,200 to 1,800€ | 14,940 | 25.2 | 16,856 | 29.8 |
| 1,800 to 2,700€ | 15,662 | 26.4 | 12,625 | 22.0 |
| ≥2,700€    | 16,457   | 27.8       | 8086      | 14.1     |
| Did not wish to answer | 3769 | 6.4 | 4507 | 7.8 |
| Phototype (Fitzpatrick classification) | | | | |
| I, always burns easily, never tans | 3776 | 6.4 | 3557 | 6.2 |
| II, burns easily, tans minimally | 18,195 | 30.7 | 15,621 | 27.2 |
| III, burns moderately, tans gradually | 21,136 | 35.7 | 19,364 | 33.7 |
| IV, burns minimally, tans well | 10,800 | 18.2 | 11,742 | 20.4 |
| V, burns rarely, tans profusely | 3695 | 6.2 | 4342 | 7.6 |
| VI, never burns, deep pigmentation | 1670 | 2.8 | 2883 | 5.0 |
| Living area | | | | |
| Northern France (North, Paris Basin, East, Centre-East, West) | 45,296 | 76.4 | 44,022 | 76.6 |
| Southern France (South-West, Mediterranean Basin) | 13,977 | 23.6 | 13,486 | 23.4 |
| Size of the urban unit | | | | |
| Rural community | 12,995 | 21.9 | 14,607 | 25.4 |
| Urban community < 200,000 inhabitants | 19,277 | 32.6 | 20,170 | 35.1 |
| Urban community ≥ 200,000 inhabitants | 26,952 | 45.5 | 22,686 | 39.5 |
| Vitamin D supplement or drug use ¹ | | | | |
| Yes | 7622 | 12.9 | 6087 | 10.6 |

¹ Participants were considered to already have taken a vitamin D supplement/drug if they declared taking a vitamin D supplement or a drug containing vitamin D in the dietary supplement questionnaire or in any health questionnaire prior to the questionnaire investigating vitamin D knowledge.

Among participants with available plasma 25-hydroxyvitamin D (25OHD) concentration (N = 700, Table 3, mean 25OHD concentration = 24.5 ± 11.8 ng/mL), only 30% of those who believed that their VitD status was too low did have an insufficient VitD status (<20 ng/mL) and only 16% of those with an actual VitD insufficiency were concerned with their VitD status.

3.3. VitD Sources (Table 4, Table S3)

Sun exposure as a source of VitD was cited by 72% of participants. This source was better known by women, participants with higher educational level and income, and with adequate VitD status (83% vs. 75% in those with insufficient status, p = 0.01, not tabulated).

A total of 62% of the participants cited drugs containing VitD, 61% fatty fish, 55% cod liver oil and 51% VitD-fortified dairy products. Women had a better knowledge of these sources. Younger participants, those with a higher educational level and income were more likely to cite fortified dairy products and supplements/drugs containing VitD and less likely to mention traditional dietary sources. Participants who had ever taken VitD supplements/drugs had a better knowledge of VitD sources overall, as did participants who were concerned that their VitD status was too low.
Table 2. Sources of information regarding vitamin D and concerns regarding vitamin D status overall and according to age, sex and educational level, NutriNet-Santé cohort, France 2009–2015.

| Source of Information | Overall | Sex | Age | Educational Level |
|-----------------------|---------|-----|-----|-------------------|
|                       | N       | %   | N   | %               | N   | %   | N   | %               |
| Have you ever heard of vitamin D? | <0.0001 |      | <0.0001 |      | <0.0001 |      |
| Yes                   | 52,873  | 91.9| 29,111 | 94.9| 23,762 | 88.6| 13,334 | 90.4| 19,191 | 90.4| 20,347 | 94.5| 30,451 | 90.7| 8490 | 92.6| 13,932 | 94.4 |
| No                    | 2942    | 5.1 | 987  | 3.2 | 1955   | 7.3 | 852    | 5.8 | 1422   | 6.7 | 688    | 3.1 | 1927   | 5.7 | 460   | 5.0 | 555   | 3.8 |
| I don’t know          | 1693    | 3.0 | 576  | 1.9 | 1117   | 4.2 | 560    | 3.8 | 612    | 2.9 | 521    | 2.4 | 1212   | 3.6 | 213   | 2.3 | 268   | 1.8 |

Where/did you hear of vitamin D? (multiple choices)

| Source of Information | Overall | Sex | Age | Educational Level |
|-----------------------|---------|-----|-----|-------------------|
|                       | N       | %   | N   | %               | N   | %   | N   | %               |
| At your physician's   | 21,467  | 40.6| 14,787 | 50.8| 8680   | 28.1| <0.0001 | 4052 | 30.4| 7758   | 40.4| 9658   | 47.5| <0.0001 | 13,519 | 44.4| 2985   | 35.2| 4963   | 35.6 |
| At another healthcare professional's   | 7357    | 13.9| 4623  | 15.9| 2734   | 11.5| <0.0001 | 2174 | 16.3| 2594   | 13.5| 2590   | 12.7| <0.0001 | 3982 | 13.1| 1231   | 14.5| 2145   | 15.4 |
| In newspapers        | 13,842  | 26.2| 6675  | 22.9| 7168   | 25.7| <0.0001 | 3076 | 23.1| 4928   | 25.7| 5839   | 28.7| <0.0001 | 8201 | 26.9| 2206   | 26.0| 3435   | 24.6 |
| In magazines         | 20,438  | 38.7| 11,245 | 38.6| 9192   | 31.5| 4196   | 31.5| 7197   | 37.5| 9044   | 44.4| <0.0001 | 12,208 | 40.1| 3246   | 38.2| 4984   | 35.8 |
| On the radio         | 9765    | 18.5| 4136  | 14.2| 5629   | 23.7| <0.0001 | 2028 | 15.2| 3611   | 18.8| 4126   | 20.3| <0.0001 | 5863 | 19.2| 1500   | 17.7| 2402   | 17.2 |
| On the television    | 20,746  | 39.2| 10,396 | 35.7| 10,350 | 43.6| <0.0001 | 5936 | 44.5| 7346   | 38.3| 7464   | 36.7| <0.0001 | 12,380 | 40.7| 3655   | 43.0| 4712   | 33.8 |
| From relatives or friends   | 7412    | 14.0| 3428  | 11.8| 3984   | 16.8| <0.0001 | 2168 | 16.3| 2841   | 14.8| 2403   | 11.8| <0.0001 | 4021 | 13.2| 1188   | 14.0| 2202   | 15.8 |
| At school/university  | 9853    | 18.6| 5677  | 19.5| 4176   | 17.6| <0.0001 | 4530 | 15.9| 2275   | 11.2| <0.0001 | 2868 | 9.4| 2386   | 28.1| 4598   | 33.0 |
| Elsewhere             | 5471    | 10.4| 2215  | 7.6 | 3256   | 13.7| <0.0001 | 1731 | 13.0| 2296   | 12.0| 1443   | 7.1 | <0.0001 | 2762 | 9.1| 1113   | 13.1| 1595   | 11.4 |
| I don’t remember      | 4589    | 8.7 | 1960  | 6.7 | 2628   | 11.1| <0.0001 | 1255 | 9.4| 1942   | 10.1| 1392   | 6.8 | <0.0001 | 2557 | 8.4| 598   | 7.1 | 1434   | 10.3 |

I think that my vitamin D status is too low

| Source of Information | Overall | Sex | Age | Educational Level |
|-----------------------|---------|-----|-----|-------------------|
|                       | N       | %   | N   | %               | N   | %   | N   | %               |
| Agree                 | 12,576  | 23.8| 9069 | 31.2| 3507   | 14.8| <0.0001 | 4298 | 22.4| 5268   | 25.9| 7620   | 25.0| 1722   | 20.3| 3233   | 23.2 |
| Disagree              | 15,449  | 29.2| 8045 | 27.6| 7404   | 31.2| <0.0001 | 4432 | 35.6| 5311   | 27.1| 5796   | 28.0| 7875   | 25.9| 4359   | 36.9 |
| I don’t know          | 24,849  | 47.0| 11,998 | 41.2| 12,851 | 51.4| <0.0001 | 5893 | 44.2| 9583   | 49.9| 9373   | 46.1| 14,956 | 49.1| 6254   | 44.9 |

1 p for the comparison of answers between categories using $\chi^2$ tests; 2 p for the comparison of answers between categories using $\chi^2$ tests from unconditional logistic regression models adjusted for age (<35 years, 35–55 years, ≥55 years) and sex. When three answers were possible (ex: “Agree/Disagree/I don’t know”), polytomous unconditional logistic regression models adjusted for age and sex were used; 3 Only participants who answered “Yes” to this question had access to the other questions. Bold values are the ones for which >5% difference was observed between categories.
Table 3. Opinion regarding vitamin D status and measured vitamin D status, NutriNet-Santé cohort, France 2009–2015.

| Vitamin D status | Overall | Agree | Disagree | I don’t know |
|------------------|---------|-------|----------|--------------|
| <20 ng/mL (insufficiency) |  
| N | 276 | 45 | 75 | 156 |
| % (line) | 100 | 16.3 | 27.2 | 56.5 |
| % (column) | 39.4 | 30.4 | 35.1 | 46.2 |
| ≥20 ng/mL |  
| N | 424 | 103 | 139 | 182 |
| % (line) | 24.3 | 24.3 | 32.8 | 42.9 |
| % (column) | 60.6 | 69.6 | 64.9 | 53.8 |
| Overall | 700 | 148 | 214 | 338 |
| % (line) | 100 | 21.1 | 30.6 | 48.3 |

\(^1\) \(p\) for the comparison of answers between measured vitamin D status and opinion regarding vitamin D status using \(\chi^2\) tests from unconditional logistic regression models adjusted for age (<35 years, 35–55 years, ≥55 years) and sex. When three answers were possible (ex: “Agree/Disagree/I don’t know”), polytomous unconditional logistic regression models adjusted for age and sex were used.

While the main sources of VitD were insufficiently known, participants also cited olive oil (18%), white fish (11%), antioxidant supplements (7%) or chicken (4%), showing some existing confusion.

Overall, 6% of participants agreed that tanning booths/sunbeds from tanning salons can provide VitD and especially younger participants, those with a higher educational level and participants who declared a high usual sun exposure (9% vs. 5% for moderate or low sun exposure, \(p < 0.0001\), not tabulated).

3.4. Role of VitD in Several Health Conditions (Table 5, Table S4)

Only 78% of participants associated VitD to healthy bones, 74% to osteoporosis and 62% to rickets. These proportions were higher in women, older participants and those who already took VitD supplements/drugs. Only 40% acknowledged a role of VitD in pregnancy, and especially women, younger participants, those with a higher educational level, and those who took VitD supplements/drugs.

While these consensual roles of VitD were not well known, a substantial proportion of participants associated VitD with several other health conditions for which a consensus has not yet been reached (even though ongoing research provides promising results), such as skin cancers (33%), skin diseases (26%), other cancers (25%), infections (25%), or psychiatric diseases (11%).

3.5. Knowledge/Beliefs Regarding VitD According to the Source of Information (Table S5)

Participants who learned about VitD from their physician were more likely to have a better knowledge of VitD sources and clearly established health effects. Participants who learned about VitD with another healthcare professional (e.g., pharmacist, dietician, dentist, nurse, etc.) or at school/university also answered correctly for VitD sources and health effects but also tended to associate VitD with other health conditions with unclear consensus, as did participants who learned about VitD in the media.

All results remained statistically significant after Bonferroni correction to take into account multiple testing.
Table 4. Knowledge regarding sources of vitamin D overall and according to sex, age and educational level, NutriNet-Santé cohort, France 2009–2015.

| From where do you think the body can obtain vitamin D? (multiple choices) | Overall | Sex | Age | Educational Level | χ² | p ¹ | Overall | Sex |Age | Educational Level | χ² | p ² |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | % | N | % | p ¹ | N | % | N | % | p ¹ | N | % | N | % | p ² |
| Fatty fish | 32,476 | 61.4 | 19,125 | 65.7 | 13,351 | 56.2 | <0.0001 | 6938 | 52.0 | 11,403 | 59.4 | 14,136 | 69.5 | <0.0001 | 19,223 | 63.1 | 4965 | 58.5 | 8288 | 59.5 | <0.0001 |
| Lean fish | 5587 | 10.6 | 2808 | 9.7 | 2779 | 11.7 | <0.0001 | 224 | 1.7 | 1121 | 5.8 | 1128 | 6.3 | <0.0001 | 2000 | 6.7 | 529 | 6.2 | 695 | 5.0 | <0.0001 |
| Cod liver oil | 28,930 | 54.7 | 17,241 | 59.2 | 11,690 | 49.2 | <0.0001 | 5557 | 41.7 | 9898 | 51.6 | 13,476 | 66.2 | <0.0001 | 17,162 | 56.4 | 4406 | 51.9 | 7362 | 52.8 | <0.0001 |
| Dairy products | 16,654 | 31.5 | 9525 | 32.7 | 7129 | 30.0 | <0.0001 | 4350 | 32.6 | 5495 | 28.6 | 6809 | 33.5 | <0.0001 | 9566 | 31.4 | 2826 | 33.3 | 4262 | 30.6 | 0.001 |
| Dairy products fortified with vitamin D | 32,623 | 61.7 | 19,730 | 67.8 | 12,894 | 54.3 | <0.0001 | 8248 | 61.9 | 11,311 | 58.9 | 13,065 | 64.2 | <0.0001 | 17,879 | 58.7 | 5421 | 63.9 | 9323 | 66.9 | <0.0001 |
| Chicken | 2291 | 4.3 | 959 | 3.3 | 1332 | 5.6 | <0.0001 | 891 | 6.7 | 648 | 3.4 | 752 | 3.7 | <0.0001 | 1367 | 4.5 | 504 | 5.9 | 419 | 3.7 | <0.0001 |
| Red meat | 3425 | 6.5 | 2026 | 7.0 | 1399 | 5.9 | <0.0001 | 774 | 5.8 | 1368 | 7.1 | 1283 | 6.3 | <0.0001 | 2200 | 7.2 | 529 | 6.2 | 695 | 5.0 | <0.0001 |
| Offal | 12,347 | 23.4 | 7760 | 26.7 | 4587 | 19.3 | <0.0001 | 2027 | 15.2 | 4566 | 23.8 | 5753 | 28.3 | <0.0001 | 17,162 | 56.4 | 4406 | 51.9 | 7362 | 52.8 | <0.0001 |
| Eggs | 12,109 | 22.9 | 7116 | 24.5 | 4993 | 21.0 | <0.0001 | 2487 | 18.7 | 4255 | 22.2 | 5368 | 26.4 | <0.0001 | 7158 | 23.5 | 1908 | 22.5 | 3044 | 21.9 | 0.003 |
| Olive oil | 9370 | 18.4 | 5283 | 18.2 | 4447 | 18.7 | 0.09 | 2121 | 15.9 | 3214 | 16.7 | 4395 | 21.6 | <0.0001 | 6035 | 19.6 | 1651 | 19.4 | 2044 | 14.7 | <0.0001 |
| Antioxidant supplements | 3850 | 7.3 | 2299 | 7.9 | 1551 | 6.5 | <0.0001 | 935 | 7.0 | 1421 | 7.4 | 494 | 7.3 | <0.0001 | 2500 | 8.2 | 574 | 6.8 | 776 | 5.6 | <0.0001 |
| Vitamin supplements | 14,089 | 26.7 | 8358 | 28.7 | 5731 | 24.1 | <0.0001 | 5155 | 38.7 | 5042 | 26.3 | 3891 | 19.1 | <0.0001 | 6600 | 21.9 | 2653 | 31.3 | 4775 | 34.3 | <0.0001 |
| Drugs containing vitamin D | 32,623 | 61.7 | 19,730 | 67.8 | 12,894 | 54.3 | <0.0001 | 8248 | 61.9 | 11,311 | 58.9 | 13,065 | 64.2 | <0.0001 | 17,879 | 58.7 | 5421 | 63.9 | 9323 | 66.9 | <0.0001 |
| Sun exposure | 37,910 | 71.7 | 22,662 | 77.9 | 15,248 | 64.2 | <0.0001 | 9742 | 73.1 | 13,422 | 69.9 | 14,747 | 72.5 | <0.0001 | 20,674 | 67.9 | 6349 | 74.8 | 10,886 | 78.1 | <0.0001 |
| I don't know | 4443 | 8.4 | 1432 | 4.9 | 3011 | 12.7 | <0.0001 | 1413 | 10.6 | 1711 | 8.9 | 1319 | 6.5 | <0.0001 | 2956 | 9.7 | 599 | 7.1 | 889 | 6.4 | <0.0001 |

<sup>1</sup> p for the comparison of answers between categories using χ² tests; <sup>2</sup> p for the comparison of answers between categories using χ² tests from unconditional logistic regression models adjusted for age (<35 years, 35–55 years, ≥ 55 years) and sex. When three answers were possible (ex: “Agree/Disagree/I don’t know”), polytomous unconditional logistic regression models adjusted for age and sex were used; <sup>3</sup> In France, fortification of foodstuffs with vitamin D is allowed but not mandatory. Bold values are the ones for which >5% difference was observed between categories.
Table 5. Beliefs regarding the role of vitamin D in health conditions, overall and according to sex, age and educational level, NutriNet-Santé cohort, France 2009–2015.

| Health Condition | Overall | Sex | Age | Educational Level |
|------------------|---------|-----|-----|------------------|
|                  | N %     | N % | N % | N % p 1          |
|                  | N %     | N % | N % | N % p 1          |
|                  | N %     | N % | N % | N % p 2          |

### Bone health
- **According to you, is vitamin D relevant for the following health conditions?**
- **Yes: 41,311 (78.1%)**
- **No: 1942 (3.7%)**
- **I don't know: 9619 (18.2%)**

| Condition | Women | Men | <35 Years | 35–55 Years | ≥55 Years | <High-School Degree | <2 Years after High-School Degree | ≥2 Years after High-School Degree |
|-----------|-------|-----|-----------|-------------|-----------|---------------------|-------------------------------|-------------------------------|
| Bone health |       |     |           |             |           |                    |                               |                               |
| Yes       | 24,761 (55.6%) | 16,551 (56.3%) | 10,198 (52.6%) | 12,353 (54.0%) | 10,198 (52.6%) | 23,937 (78.6%) | 6633 (78.1%) | 10,741 (77.1%) |
| No        | 777 (1.7%)     | 1165 (3.6%)   | 298 (1.5%)   | 456 (1.9%)  | 777 (1.7%)   | 23,937 (78.6%) | 6633 (78.1%) | 10,741 (77.1%) |
| I don't know | 3574 (7.9%) | 6046 (18.9%) | 3194 (16.8%) | 2852 (12.0%) | 3574 (7.9%) | 23,937 (78.6%) | 6633 (78.1%) | 10,741 (77.1%) |

### Osteoporosis
- **Yes: 35,477 (74.0%)**
- **No: 1,747 (3.5%)**
- **I don't know: 12,367 (22.5%)**

### Rickets
- **Yes: 32,906 (62.2%)**
- **No: 2,785 (5.3%)**
- **I don't know: 17,182 (32.5%)**

### Cancer
- **Yes: 13,081 (24.7%)**
- **No: 7,840 (14.8%)**
- **I don't know: 31,952 (60.4%)**

### Skin cancers
- **Yes: 17,375 (32.9%)**
- **No: 6,640 (12.6%)**
- **I don't know: 28,858 (52.5%)**

### Skin diseases
- **Yes: 13,727 (26.0%)**
- **No: 6,536 (12.4%)**
- **I don't know: 32,610 (61.7%)**

### Kidney diseases
- **Yes: 3,423 (6.5%)**
- **No: 11,062 (20.9%)**
- **I don't know: 38,290 (70.0%)**

### Alzheimer’s
- **Yes: 3,566 (6.7%)**
- **No: 12,306 (23.3%)**
- **I don’t know: 37,002 (70.0%)**

### Diabetes
- **Yes: 4,617 (8.7%)**
- **No: 13,966 (26.4%)**
- **I don’t know: 34,290 (64.9%)**
Table 5. Cont.

According to you, is vitamin D relevant for the following health conditions?

| Condition                          | Overall | Sex | Age | Educational Level |
|------------------------------------|---------|-----|-----|-------------------|
|                                    | N       | %   | N   | %   | N   | %   | N   | %   | N   | %   | p<sub>1</sub> | N   | %   | N   | %   | N   | %   | p<sub>2</sub> |
| Heart diseases                     | 4104    | 7.8 | 2167 | 7.4 | 1937 | 8.2 | 1048 | 7.9 | 1371 | 7.1 | 1685 | 8.3 | <0.0001 | 2461 | 8.1 | 672 | 7.9 | 971 | 7.0 |
| Yes                                | 13,795  | 26.1| 7732 | 26.6| 6063 | 25.5| 3687 | 27.7| 4748 | 24.7| 5360 | 26.3| <0.0001 | 7619 | 25.0| 2420| 28.5| 3756| 27.0|
| No                                 | 34,974  | 66.2| 19,212| 66.0| 15,762| 66.3| 8599 | 64.5| 13,073| 68.1| 13,302| 63.4| <0.0001 | 20,370| 66.9| 5398| 63.6| 9205| 66.1|
| I don’t know                       | 14,707  | 28.5| 7540 | 25.9| 5899 | 24.8| 3260 | 24.5| 5093 | 26.5| 5085 | 25.0| <0.0001 | 7859 | 25.8| 2294| 27.0| 3285| 23.6|
| Psychiatric diseases               | 5755    | 10.9| 3280 | 11.3| 2475 | 10.4| 1880 | 14.1| 2194 | 11.4| 1680 | 8.3 | <0.0001 | 3020 | 9.9 | 1041| 12.3| 1694| 12.2|
| Yes                                | 14,053  | 26.6| 7779 | 26.7| 6274 | 26.4| 3698 | 27.7| 4909 | 25.6| 5447 | 26.8| <0.0001 | 8064 | 26.5| 2322| 27.4| 3667| 26.3|
| No                                 | 33,065  | 62.5| 18,052| 62.0| 15,013| 63.2| 7757 | 58.2| 12,089| 63.0| 13,220| 65.0| <0.0001 | 19,367| 63.6| 5127| 60.4| 8571| 61.5|
| I don’t know                       | 13,439  | 25.4| 7540 | 25.9| 5899 | 24.8| 3260 | 24.5| 5093 | 26.5| 5085 | 25.0| <0.0001 | 7859 | 25.8| 2294| 27.0| 3285| 23.6|
| Infections                         | 9904    | 18.7| 5577 | 19.2| 4326 | 18.2| 2448 | 18.4| 3453 | 18.0| 4003 | 19.7| <0.0001 | 5646 | 18.5| 1576| 18.6| 2681| 19.2|
| Yes                                | 29,531  | 55.9| 15,994| 54.9| 13,537| 57.0| 7626 | 57.2| 10,645| 55.5| 11,260| 55.3| <0.0001 | 16,945| 55.7| 4620| 54.4| 7966| 57.2|
| No                                 | 12,067  | 23.6| 7076 | 23.7| 5414 | 22.9| 2968 | 22.0| 4214 | 21.6| 4717 | 23.4| <0.0001 | 8064 | 26.5| 2322| 27.4| 3667| 26.3|
| I don’t know                       | 21,109  | 42.7| 14,294| 49.1| 6815 | 28.7| 6467 | 48.5| 7982 | 41.6| 6661 | 32.7| 11,326| 37.2| 3736| 44.0| 6048| 43.4|
| Yes                                | 6328    | 12.0| 3058 | 10.5| 3270 | 13.8| 1482 | 11.1| 2040 | 10.6| 2805 | 13.8| <0.0001 | 3865 | 12.7| 1016| 12.0| 1447| 10.4|
| No                                 | 25,456  | 51.3| 13,076| 45.0| 13,269| 53.8| 5385 | 40.4| 9170 | 47.8| 10,881| 53.3| <0.0001 | 15,261| 50.1| 5738| 44.0| 6438| 46.2|
| I don’t know                       | 3314    | 6.6| 2087 | 7.2| 1228 | 5.2 | 322  | 2.4| 900 | 4.7| 2093 | 10.3| <0.0001 | 2645 | 8.7 | 324 | 3.8 | 346 | 2.5 |
| No health effect                   | 34,988  | 66.2| 19,741| 67.8| 15,248| 64.2| 10,317| 77.4| 12,576| 65.5| 12,096| 59.5| 17,695| 58.1| 6336| 74.6| 10,958| 78.7 |
| Yes                                | 14,570  | 27.6| 7284 | 25.0| 7286 | 30.7| 2696 | 20.2| 5716 | 29.8| 6159 | 30.3| <0.0001 | 10,111| 33.2| 1831| 21.6| 2629| 18.9 |

1<sup>1</sup> <sup>1</sup> p for the comparison of answers between categories using χ<sup>2</sup> tests; 2<sup>2</sup> p for the comparison of answers between categories using χ<sup>2</sup> tests from unconditional logistic regression models adjusted for age (<35 years, 35–55 years, ≥55 years) and sex. When three answers were possible (ex: “Agree/Disagree/I don’t know”), polytomous unconditional logistic regression models adjusted for age and sex were used. Bold values are the ones for which >5% difference was observed between categories.
4. Discussion

To our knowledge, this study is the first to assess VitD-related knowledge of a large European sample from the general population. While sources and established health effects of VitD were not always cited by participants, substantial proportions of subjects mentioned incorrect sources and health effects for which the role of VitD is still debated. Knowledge was strongly influenced by the source of information and sociodemographic and economic factors. Interestingly, a high inconsistency was observed between what people think about their VitD status and their actual status.

Although 30% of participants did not mention sun exposure (primary source of VitD [40]), this source was the most frequently cited, consistently with previous studies in which high proportions of people associated sunshine with VitD [19,24,28,29,32,34,35].

Tanning booths/sunbeds have been promoted by the industry as a VitD provider [41]. Of our population, 6% agreed with this argument, especially the youngest group. This is of concern since these devices are also strongly associated with skin aging/skin cancer [41,42]. Thus, they should not be recommended as a way to get VitD, especially in young people (susceptible group for skin cancer) [43].

Dietary sources of VitD mainly include cod liver oil, fatty fish, eggs, offal, dairy products (especially if fortified) and some mushrooms, although the contribution of these sources to VitD status is low compared to sun exposure [40,44]. In our population, as in previous studies [19,21,28,29,32–36], knowledge regarding VitD dietary sources was insufficient and contrasted, depending on the source. Fatty fish, cod liver oil or fortified dairy products were known by 50%–60% of our participants while regular dairy products, offal or eggs were only known by 20%–30%. Some confusion was also observed since 18% of participants cited olive oil and 5%–10% lean fish or chicken while they contain no/very little VitD. Incorrect VitD sources such as fruits, vegetables, soya or rice were also cited in previous studies [28,32,34,36].

Thus far, the “classic” roles of vitamin D in musculoskeletal health have been clearly established [4,17]. In contrast, although results from several types of studies have been very promising regarding the “non-classic” non-musculoskeletal effects of VitD [1,2,8,9,13], for the moment, an overall lack of clear consensus remains for these outcomes.

Concurrently, the media has circulated a lot of information on VitD and often failed to balance these assertions by distinguishing consensus knowledge from promising ongoing research [18]. This has resulted in some confusion regarding VitD health effects, in both the public and health professionals [20,28], as reflected by the present study.

The established role of VitD in bone health was known to a majority of participants but unknown to 22%–38% of them. These were also identified as main VitD health effects in previous studies [19,24–26,28,29,34,36].

Although VitD effects on several pregnancy outcomes (e.g., pre-eclampsia, pre-term birth, gestational diabetes) are still under research, its role in the prevention of neonatal hypocalcaemia has been recognized and VitD supplementation of pregnant women is recommended in France [45,46]. However, in our population, only 40% of participants were aware of a role of VitD in pregnancy.

Participants also attributed a role to VitD in other health conditions such as cancers, cardiovascular or cognitive diseases, as previously observed [19,26,28,34–36]. A better understanding of the role of VitD in these health outcomes represents interesting research perspectives and is needed to achieve a clear consensus. Thus, the current state of the scientific consensus does not allow definite answers.

Believing that VitD is involved in all sorts of health conditions may lead participants to search for VitD supplementation whereas this should only target individuals at risk of VitD insufficiency since long-term consequences of high VitD status are still uncertain [4,47].

About a quarter of our population thought they had an insufficient VitD status. Corresponding proportions in previous studies were 9% (Australia) and 6% (New Zealand). Surprisingly, while participants with darker skin are more at risk of insufficiency [1,38], they were the least concerned with their VitD status in our study, consistently with an Australian study on general practitioners [22] in which dark skin was not considered as a main risk factor for VitD insufficiency.
Prevalence of VitD insufficiency (25OHD < 20 ng/mL) was about 40% in our subsample from the general population. Interestingly, concern with VitD status and actual insufficiency were largely inconsistent: only 16% of those with an insufficient VitD status thought they were insufficient, and 30% of those who were concerned with their VitD status were actually insufficient. People living in the northern regions of France were more concerned about their VitD status and rightfully so since it was observed that they were more likely to have an insufficient VitD status. Indeed, in a study on a representative sample of the French population [6], 26% of individuals living in the sunniest southern regions had a 25OHD blood concentration below 20 ng/mL, vs. 46%–47% in the northern regions. In our subsample from the NutriNet-Santé study (N = 732), corresponding proportions were 43% in the northern regions and 31% in the southern regions. In Europe, contrary to expectations, the prevalence of low VitD status did not align perfectly with the latitude or region-based UVB doses [7,48–50]. Low VitD status was observed to be more frequent in mid-latitude countries (e.g., UK, Ireland, Netherlands, Germany) than in northern countries (e.g., Norway, Iceland, Finland) and a higher VitD status in southern countries (e.g., Spain, Italy, Greece) was not systematically observed. This could be due to differences in sun-seeking behaviors, food intakes but also in VitD fortification policies or supplementation practices [7,48–51]. One may think that people from Northern Europe may display more awareness regarding the risk of low VitD status and thus a better VitD-related knowledge. However, to our knowledge, studies performed in Europe on this topic took place in the Netherlands [25], the UK [28] and Ireland [32], which does not allow comparison between Northern and Southern Europe. Studies in these countries would thus provide insights on the VitD-related knowledge of its inhabitants.

Physicians were the first source of information in our population, especially for women and older participants, i.e., two groups at higher risk of VitD insufficiency or bone-related disorders. This source was associated with better knowledge regarding VitD. Previous studies have shown that physicians are a major source of VitD-related information [19,23,28,31,35]. This highlights the important role played by physicians (trusted source of information) in the education of their patients [20,23,25,26].

However, people usually rely on diversified sources of information [20]. When all types of media were grouped, they were cited by 63% of our participants (men especially), becoming the leading source of information, as observed in previous studies [23,28,35,36]. In our study, participants who learned about VitD in the media (all types) were more likely to associate VitD with health effects for which a clear consensus is still needed. This may result from the confusing message expressed by some media [18,23].

In this study, women had a more accurate knowledge than men regarding VitD sources and the role of VitD in bone health and pregnancy. They were also more concerned with their VitD status. This was previously observed [26,33,35,36] and may be due to the fact that women usually show more interest in nutrition- and health-related issues but also that, as an “at-risk” group for VitD insufficiency and bone-related disorders, they may be more informed by their physicians, as observed in our study.

In addition, an age and/or generational effect was observed in our study as in previous ones [26,28,35,36]. Older participants had a better knowledge of cod liver oil and rickets, in line with a London study [28] and consistent with the fact that, as children, older people used to receive cod liver oil at school to prevent rickets, whereas the term “rickets” may not even be known by younger participants. Older participants (“at-risk” group) were also more likely to have heard of VitD from their physician which may have resulted in their better knowledge regarding its role in bone health. In contrast, younger participants (especially women) as expected were more aware of a role of VitD in pregnancy. They were also more likely to have heard of VitD at school/university. Older participants more frequently cited classic dietary sources of VitD and younger ones cited supplements and fortified dairy products.

As in previous studies [26,36], a higher socioeconomic position was also associated with a better VitD-related knowledge overall.
Some limitations should be acknowledged. First, our population was composed of volunteers involved in a nutrition-and-health cohort. Therefore, the extrapolation of our results to the entire French population needs caution since our results may overestimate VitD-related knowledge. However, this large and diverse population sample was weighted to be representative of the French adult population in terms of sociodemographic and economic characteristics. Second, this was a multiple-choice questionnaire, meaning that all answers were prompted. This may have induced some hindsight bias and an overestimation of VitD-related knowledge [26,35]. Last, participants did not have the opportunity to freely answer. For example, in the sources of information regarding VitD, “Internet” was not a proposed choice, whereas it has been shown to be an important source of information on nutrition and health [52].

5. Conclusions

In a context where vitamin D (VitD) arouses considerable interest in the public and the medical and scientific community, this study, the first in Europe to have such a large sample, provided detailed information on knowledge and beliefs of a general adult population regarding this particular nutrient. These results have highlighted that not only physicians, but also the media, are key information providers on this topic, and that people are getting confused with the health effects and sources of VitD. These findings were modulated by age/generational and socioeconomic factors (overall better knowledge in women, better-educated and higher-income individuals). Moreover, a strong inconsistency was observed between participants’ opinion on their VitD status and actual insufficiency.

Information about VitD needs to be improved: (1) healthcare professionals should be better trained regarding the health effects of VitD (current state of knowledge and consensus for each outcome, possible long-term consequences of a high VitD status) and risk factors for VitD insufficiency (which can be summarized with a score [38]); (2) the public should receive information that reflects the actual state of knowledge and ongoing research regarding VitD and its association with health, along with clear information on VitD sources (especially the duration of sun exposure needed to produce VitD, compatible with skin cancer prevention). This may partly contribute to improved VitD status in the population and optimisation of VitD supplement prescription.

Supplementary Materials: The following are available online at http://www.mdpi.com/2072-6643/8/11/718/s1, Table S1: Translation of the online questionnaire regarding vitamin D knowledge, NutriNet-Santé cohort, 2009–2015; Table S2: Sources of information regarding vitamin D and concerns regarding vitamin D status according to monthly income per household unit and vitamin D supplement or drug use, NutriNet-Santé cohort, France 2009–2015; Table S3: Knowledge regarding sources of vitamin D according to monthly income per household unit and vitamin D supplement or drug use, NutriNet-Santé cohort, France 2009–2015; Table S4: Beliefs regarding the role of vitamin D in health conditions according to monthly income per household unit and vitamin D supplement or drug use, NutriNet-Santé cohort, France 2009–2015; Table S5: Knowledge regarding vitamin D sources and beliefs regarding the role of vitamin D in health conditions according to the source of information, NutriNet-Santé cohort, France 2009–2015.

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