

Senior citizens' vitamin D supplements intake: evidence from Denmark

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Abstract

BACKGROUND: Several public interventions have been designed in recent years to urge the intake of vitamin D supplements among the senior population to avoid the direct and indirect consequences associated with vitamin D deficiency. However, the effectiveness of these public campaigns remains quite limited. In an online survey, the current study investigates attitudes towards vitamin D supplements intake and associated behaviours in a representative sample of Danish senior citizens ($N = 554$) – that is, individuals aged 55 years and above.

RESULTS: Approximately half of the sample reported taking vitamin D supplements in the preceding year. Furthermore, being male and having a positive perception of individuals' own health status increased the probability of being a non-user. Increasing confidence in the information provided by health authorities (such as medical doctors and pharmacies) is particularly critical for enhancing the likelihood of non-users to purchase vitamin D supplements. However, also encouraging the uptake of vitamin D supplements in specialized supermarkets with stands and promotions seems an appealing and practical solution to increase seniors' uptake of vitamin D supplements.

CONCLUSIONS: The present study outlines the characteristics of senior Danish non-users of vitamin D supplements. Additionally, the research provides information on the strategies that could be applied by public organizations to foster vitamin D supplements intake among this target segment of the population.

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INTRODUCTION

Numerous studies conducted in Europe and worldwide have shown substantial vitamin D insufficiency and deficiency.¹ In Denmark estimates vary from 10% up to 54%, depending on the time of year and studied population.² Because of the multiple roles of vitamin D for human physiology, its low serum concentrations may pose a health risk.³ Sources of vitamin D in the human body include biosynthesis induced by ultraviolet B (UVB) light and dietary intake. However, a limited number of foods are a rich source of vitamin D (e.g., fatty fish), and the consumption of such foods generally has an insufficient impact on overall vitamin D status.^{4,5} Vitamin D deficiency is especially problematic at high latitudes, such as northern European countries (55–72° N), because sun exposure and the intensity of UVB irradiation during winter are not sufficient for vitamin D biosynthesis. Therefore, the most important approaches to alleviate vitamin D deficiency consist of fortifying foods and recommending dietary supplements to vulnerable segments of the population.^{6,7} Accordingly, some of the Nordic countries have started national policies of voluntary, mandatory or recommendation-based fortification to ensure adequate

vitamin D supplementation for specific risk groups (for a complete overview see the work of Itkonen *et al.*)⁸

In Denmark, vitamin D fortification must be approved by the Danish Veterinary and Food Administration.⁸ As Danes on the one hand tend to be sceptical towards vitamin D-enriched foods, but on the other hand are very accepting of dietary supplements,^{8,9} fortification has hitherto not been perceived as a viable route to remedying vitamin D deficiencies in the Danish population. Therefore, a different vitamin D policy approach has been taken. This involves a voluntary pathway that targets individuals – that is, members of vulnerable groups – to ensure their own personal vitamin D sufficiency by taking supplements.

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However, the extent to which vulnerable groups can be reached by this approach, and how users and non-users of vitamin D within the targeted groups can be characterized, are unknown. Furthermore, the kinds of persuasive measures that may be used to reach the non-compliant, at-risk groups are unclear.

In Denmark, 43% of men and 24% of women above 60 have low vitamin D status in spring.² The Danish Health Authority has drawn particular attention to this senior citizen segment, a particularly vulnerable population group with a higher prevalence of low vitamin D levels and associated health risks.¹⁰ In detail: 'a vitamin D supplement of 10 µg is recommended for people with dark skin and for people who get very little sun exposure to the skin due to very little time spent outdoors or wearing a covered up outfit; if you are over 65 and worried about getting enough vitamin D, you can take a daily supplement of 5–10 µg (400 IU) of vitamin D; if you are over 70, it is recommended that you take a daily supplement of 20 µg (800 IU) of vitamin D combined with 800–1000 mg of calcium, whether you drink milk or eat dairy products'.¹¹ The only substantial dietary source in the Danish diet is fish, but even with fish in the diet 95% of the population have vitamin D intake that is below 12 µg and without fish below 3 µg.¹²

The following study adds to the existing literature on strategies to ensure vitamin D sufficiency in vulnerable populations. Specifically, a representative sample of the Danish elderly population (latitude 56° N) who are recommended to take a specific dose of vitamin D supplements based on condition and age was analysed.¹³ Although the official recommendations explicitly refer to the over-65s, the study included also the first segment of the population entering the target age for specific recommendations (55–65 years) to monitor and raise awareness of the potential risks of this important group.

In general, the intent is to investigate the level of acceptance and the drivers of vulnerable consumers' choice.^{14–16} In detail: the first objective of this study was to understand vitamin D intake among Danish senior citizens (aged 55 years and above). Specifically, the profile of users and non-users of vitamin D supplements was investigated to identify the general characteristics affecting the likelihood of being a non-user. The second objective was to identify stimuli that may increase the likelihood of seniors to buy vitamin D supplements. Specifically, vignettes diversified by scenario and source of information were structured to indirectly stimulate the senior citizens to purchase vitamin D supplements. The third objective was to identify which factors affect the likelihood of purchasing vitamin D supplements for the segment most at risk (non-users) and most vulnerable (seniors aged over 70), providing insights to policy makers to plan ad hoc interventions aimed at increasing vitamin D intake among this population segment.

Conceptual model

Taking the voluntary route of persuasion to promote intake of vitamin D among the Danish senior population requires understanding of the factors that influence adopting health-related behaviours. Our approach was inspired by the Health Belief Model (HBM),¹⁷ which acknowledges the role of perceived threat and health motivation as important factors in health behaviour decision-making (Fig. 1). This model emphasizes the influences consumers face when engaging in preventative health behaviours and is therefore relevant when examining supplement intake. Taking a vitamin D supplement is a health behaviour that is linked, not only to preventing a vitamin D deficiency as a direct outcome, but also to reducing a risk of other negative

health-related outcomes, such as deterioration of bone health and immune functions. This makes it difficult to define the exact negative outcome of having low vitamin D status, and therefore we concentrated on overall perception and motivations related to vitamin D and its possible outcomes. The HBM emphasizes the strong influences from the consumers themselves, starting with basic demographic and psychographic variables, but also the individual's beliefs about the specific health behaviour. These beliefs relate not only to specific health behaviour but also to self-efficacy and perceived barriers to action.¹⁷ The likelihood of performing the preventative health behaviour can also be influenced by cues in the behaviour context that nudge the consumer in the direction of the choice. In the current study we focus on the context in which the consumer is presented with vitamin D intake, as well as the source of the information on the importance of vitamin D intake.

In our approach we used vitamin D concern as perceived threat measure, as it describes how much people worry about their vitamin D intake, and the health motivation was measured by attitudes towards vitamin D supplements. We included 'negative attitude towards vitamin D supplements' in our model as it reflects the motivation and describes a possible barrier against adopting vitamin D supplements in the diet. The HBM model also includes cues to action as important promoters of health behaviours. In our study we used these cues in vignettes to study how the different types of cues would promote the intention to buy/use vitamin D supplements, with a specific focus on those senior citizens not yet taking them. Successful persuasion via information requires that the sources of information are trusted. The cues to act presented in vignettes in our study had different reference sources of information and we included in our approach a measure of trust in different sources. If the purpose is to convert current non-users of supplements into users, we need to know which information sources are trusted and how the level of trust influences the target group's intentions to buy/use supplements.

MATERIAL AND METHODS

Procedure and sample

The project was registered at Aarhus University, and it was carried out in accordance with Aarhus University's guidelines for good scientific practice.¹⁸ Informed consent was obtained from all respondents. Data were collected in Denmark through an online survey, including a vignette experiment with a between-subjects design, in September 2018. A cross-sectional study design with a stratified purposive sampling procedure was implemented for targeting the senior citizen population. The professional recruitment agency Userneeds (<https://norstat.dk/norstat-og-userneeds>) was asked to recruit participants above the age of 55 and fulfil quotas based on sex and age in order to ensure a representative sample. Further details about the demographic distribution of the sample can be found in Table 1. We aimed at a sample size of 600 respondents in total in order to ensure a sufficient sample size for each of the vignette conditions. During the study, respondents were randomly assigned to three out of five different vignettes (more details can be found in the section on 'Profile of (non-)users of vitamin D supplements', below).

Questionnaire

To address the research objectives, the questionnaire was structured as shown in Fig. 2.

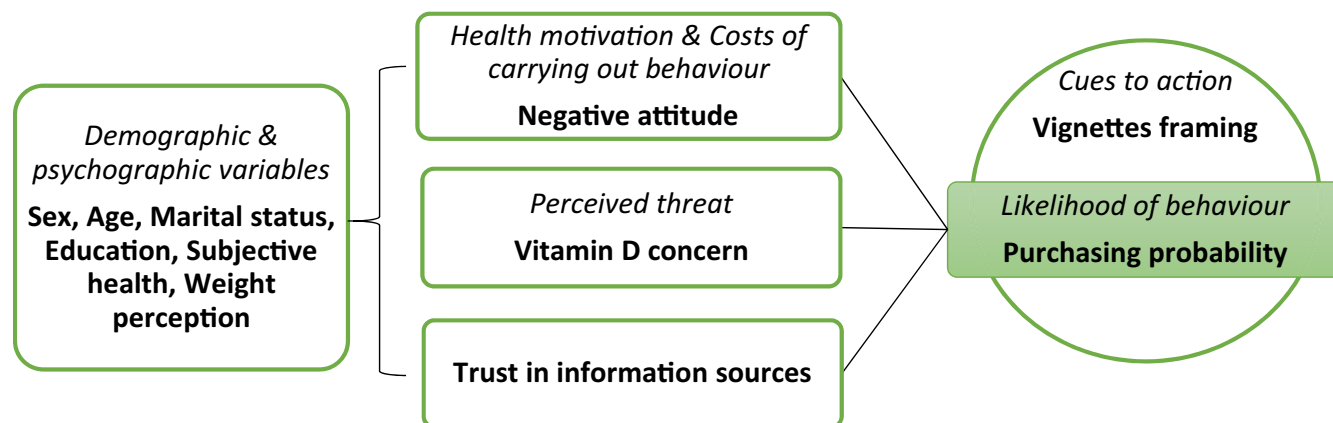


Figure 1. Conceptual model of the study informed by the Health Belief Model.

Table 1. Sample characteristics (N = 554)

Sex at birth	Male	50.2%
	Female	49.8%
Age group	55–65 years	36.6%
	65–69 years	23.1%
	70+ years	40.3%
Region	Hovedstaden	35.2%
	Midtjylland	22.6%
	Syddanmark	18.8%
	Sjælland	17.1%
	Nordjylland	6.3%
Marital status	Married/cohabiting	67.5%
	Divorced/widowed	16.2%
	Single	15.2%
	Other	1.1%
Education	Elementary school	7.2%
	Youth education	1.4%
	Skilled or short-term higher education	35.7%
	Bachelor/professional bachelor or equivalent	35.4%
	Bachelor's degree or equivalent	17.7%
	Other	2.6%

The first section collected socio-demographic information (such as gender, age, marital status, residence, education, physical and health parameters) and the height and weight of the respondents, allowing calculation of individual body mass index (BMI).

The second part of the survey used the indirect approach of vignettes – that is, short stories.¹⁹ In our specific case, vignettes described people being encouraged to take vitamin D supplements in different contexts of everyday life: being exposed to advertisement while shopping; seeing a good bargain in the supermarket; attending to a discussion in the media; receiving advice from one's doctor or from a close friend, respectively (see Appendix for the full version of the vignettes). These stimuli⁹ were intended to prompt the respondent to take actions in line with

⁹Consistent with social psychology theories, peer pressure – that is, the pressure to conform (to do what others do) – can be powerful and difficult to resist: an individual might feel pressure to do something just because peers are doing it (or saying they are doing it), indirectly conditioning specific behaviour.²⁰

the protagonist of the vignette, with whom he or she shared gender (we exploited the information previously revealed in the questionnaire) and age. Each respondent was randomly shown three of the five vignettes and, at the end of each vignette, was asked the likelihood that the protagonist would buy vitamin D as a result of the experience on a 7-point scale (from 1 'Not at all likely' to 7 'Very likely'). The different communication sources and contexts for each vignette also allowed us to evaluate possible more persuasive scenarios to stimulate interest in vitamin D supplements among the elderly. The vignettes were authored by the research team with the specific goal in mind to cover the different contexts in which the target group could potentially be made aware of vitamin D intake, and also to cover the range of different information sources that could inform them about the issues of a vitamin D deficiency. These contexts and information sources were discussed among the research team, as well as with external experts in the area. The comprehensibility of the included messages was checked among lay people and the correctness with experts before the survey was distributed.

An example of a vignette with input from a close friend is presented below. If the respondent had indicated her gender as woman, the text was adapted accordingly. An example of the vignette applied is: *'Susanne invited a group of old friends, all of your age, to her house for a nice evening. Cards are played, conversation is lively, and spirits are high. One of the friends has the phone lying on the table. The phone rings suddenly: it is an alarm. "Time for my daily dose," says the friend cheerfully, getting up and going to the kitchen. He takes some pills from a box, puts them in his mouth and rinses them out with a glass of water. He comes back smiling and explains: When you get to our age, keeping fit and healthy is almost a full-time job, and my daily dose of vitamin D and calcium supplements helps me with that.'*

Afterwards, respondents' subjective perception of their general health status was measured through questions from the National Health Profile, which is a survey on general health and development.¹³ In addition to the dichotomous question about the consumption of vitamin D supplements in the past year, respondents who were already users were asked about the period of intake, frequency of intake and type.

The questionnaire presented a direct question on how concerned the respondents were specifically about taking too little vitamin D, with options ranging from 1 'Not at all concerned' to 7 'Very concerned', and a scale on the general level of concern was also included.²¹ The hypothesis was that higher levels of

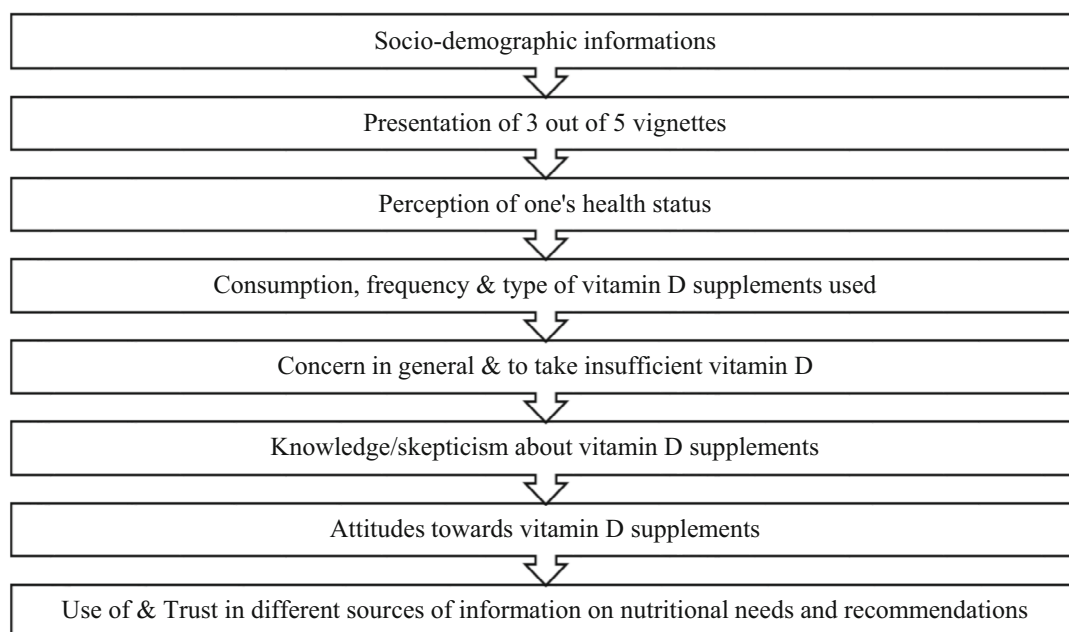


Figure 2. Survey flow.

worry would generally lead to a higher level of concern for vitamin D intake as well. A short pilot test with 150 respondents was conducted prior to the start of actual data collection, as it was necessary to test the above-mentioned scale of concern in a Danish context.²¹ This was the only scale tested in the pre-test in order to determine which items from the scale to include in the main survey. Based on a factor analysis, the four statements with the highest score were included in the survey (see Appendix Table A1 for the items chosen) and the correlation between being more worried in general and being more worried about getting enough vitamin D was confirmed ($r(148) = 0.269, P < 0.001$).

Information on respondents' knowledge/scepticism about vitamin D was measured through a series of items adapted from Jahn *et al.*⁹ High scores on this scale reflected the perceived uselessness of introducing vitamin D supplements because they were 'ancillary' to basic intake. Furthermore, the attitude of the elderly towards taking vitamin D in supplement form was measured using statements from the study by Jahn *et al.*⁹ adapted to dietary supplements instead of fortified foods. The detailed scales and corresponding elaborations are included in the Appendix (Tables A1 and A2).

Finally, respondents were asked to indicate which sources they used to seek information on nutritional needs and recommendations in general, and how much confidence they had in the various sources listed – Pharmacy, Doctor, Specialist shop, Public authorities, Health food shops, Supermarkets, Friends, Internet, TV, Magazines and newspapers – through a 7-point scale ranging from 1 'No confidence' to 7 'High confidence'.

Data analysis

The collected data were processed using STATA 16 statistical software. Cronbach's alpha values higher than 0.70 were recorded for reliability of the collected scales (General concern and Vitamin D scepticism; for more details see Table A1), and an exploratory factor analysis was conducted for both the scale on attitude (Table A2) and trust placed in sources (Table A3). Specifically,

the attitude scale produced two explanatory factors, of which only the dimension 'negative attitude' was applied in the subsequent elaborations. This is because holding a positive predisposition towards the use and purchase of vitamin D supplements is less informative for the current research objectives. Instead, all three explanatory factors resulting from the factorial for trust placed in sources were implemented in the final elaboration. A logistic regression delineated the profile of non-users of vitamin D supplements; one-way analysis of variance (ANOVA) and pairwise *t*-tests defined the differences between the groups considered for the five vignettes. Subsequently, correlation analyses defined the variables to be applied in linear regression models to identify the drivers of vitamin D supplement purchasing among over-70 non-users. Table A4 in the Appendix summarizes the variables used in the models applied to address the three core research objectives.

RESULTS

Sample characteristics and use of vitamin D supplements

The questionnaire was completed by a total of 606 respondents, 52 of whom were excluded due to inattentive responses (less than 5 min answer time). The final data included 554 responses from Danish citizens aged between 55 and 89 years, with an average age of 68 years and equally distributed by gender (49.8% women). Gender was compared with data from Statistics Denmark (2018), noting a slight imbalance in the distribution, as in the 2018 there was a distribution of 52% women and 48% men aged 55–90.

The data were collected in the five regions of Denmark, of which the capital constitutes the majority (35.20%; see Table 1). Fifty-three percent had a university degree or beyond and about 68% had a partner when the analysis was conducted.

Respondents' self-reported weight deviated from their calculated BMI weight class: the majority (60.5%) were overweight (BMI > 25) but only 45.8% declared it (see Table 2).

Table 2. Summary of respondents' health status and frequency of use of vitamin D and calcium supplements

Perceived health	Poor	1.3%
	Not so good	12.6%
	Good	44.6%
	Very good	34.3%
	Excellent	7.2%
Perceived weight	Underweight	2.9%
	Normal weight	51.3%
	Overweight	45.8%
BMI (<i>n</i> = 545)	BMI < 18.5	1.5%
	18.5 ≤ BMI ≤ 25	38.0%
	BMI > 25	60.5%
Vitamin D user	Yes	52.4%
	No	47.6%
Vitamin D user only in winter (<i>n</i> = 290)	Yes	32.8%
	No	67.2%
Vitamin D user intake frequency (<i>n</i> = 290)	Daily	85.9%
	4–5 times a week	6.6%
	1–3 times a week	6.5%
	Less often	1.0%

Table 3. Logit regression parameter estimates (with standard error in parentheses) for the entire sample

Parameter	Non-user
<i>Age group</i>	
65–69 years	−0.326 (0.267)
Over 70 years	−0.554** (0.228)
Sex	−0.799*** (0.204)
Education	−0.083 (0.201)
Marital status	0.068 (0.217)
Subjective health	0.556*** (0.133)
Weight perception	0.199 (0.185)
General concern scale	−0.027 (0.078)
Vitamin D scepticism	0.699*** (0.086)
Negative attitude	0.304*** (0.106)
Constant	−4.302*** (0.883)
Pseudo <i>R</i> ²	0.20
χ^2	151.05 ***
Number of observations	554

Note: Logit regression parameter estimates (with standard error in parentheses) for the entire sample, with non-user as dependent variable (0/1). Bold data are statistically significant at least at 0.1. Asterisks represent statistical significance at ****P* < 0.01, ***P* < 0.05 and **P* < 0.1, respectively.

Approximately half of the sample reported taking vitamin D supplements in the last year, of which only 33% took them exclusively in the winter season. The majority of users took vitamin D daily (85.9%), and the most common types of supplements were single vitamin D (37.6%) and calcium and vitamin D mix (36.9%). Concerning the sources of information that respondents stated to use regarding nutritional needs and recommendations, 52% of the sample designated the doctor as the source mainly used, followed by the Internet with 44%, and then health professionals, social sources and retailers chosen as sources of information by 23%, 19% and 16%, respectively. When the question changed to 'the source you trust', the doctor was still the most trusted source (6.13/7), but the Internet slipped further down (4.1/7). Professionals received the highest trust scores (5.3/7 for Public authorities and Pharmacy), followed by social sources, media and retailers (3.8/7), except for magazines/newspapers, where the lowest trust was recorded (2.9/7).

Profile of (non-)users of vitamin D supplements

The first objective was to characterize the profile of Danish senior citizens respondents not using vitamin D supplements. The dependent variable is the dummy discriminating between user/non-user of vitamin D supplements, and a logistic regression model was performed (Table 3). The probability of respondents not using vitamin D supplements increases when they are male and only decreases for the over-70s (there is no statistically significant difference between the 55–65 and 65–69 age groups). As the positive perception of one's own health status increases, the probability of being a non-user increases. Conversely, the different perception of one's own weight does not significantly affect the likelihood of being a (non-)user. A higher score on the scale of negative attitude towards vitamin D supplements and scepticism about their usefulness reduces the probability of being a user, while a higher or lower level of concern in general among seniors does not significantly discriminate between users and non-users.

The vignettes framing

To address the second research objective, a one-way ANOVA investigated the persuasion effect of different vignettes on the probability to purchase vitamin D supplements between users and non-users. Those who were already taking vitamin D supplements had significantly higher scores than those who were not taking supplements, although both groups agreed on the ranking of the vignettes. Figure 3 shows how the self-reported probabilities of buying supplements are distributed in each scenario considering non-users separately from those who were already vitamin D supplement users. The medical doctor registers the highest mean score, the media vignette receives the second highest score, followed by friends, the advertisement and finally the price-related shopping scenario. Notably, for both subgroups, advertisement and friends' vignettes have the same persuasive power – significantly less than for the media and the medical doctor.

Purchasing drivers of vitamin D supplements for the high-risk segment

To investigate the third research objective, two multiple regressions (with and without socio-demographic variables) were conducted first on the whole non-user subsample (*n* = 264) and then on the most vulnerable group (non-users and aged over 70, *n* = 95) to identify possible strategies to increase vitamin D supplement intake (Table 4). The dependent variable is the respondents' indication of how likely the person in the vignettes was to buy vitamin D supplements, calculated as the mean probability value of the three vignettes they were presented with. A specific concern about not having enough vitamin D increased the likelihood of buying supplements for non-users. Similarly, greater confidence in the information provided by health authorities (medical doctor and pharmacy), media and specialist shops increased the likelihood of non-users buying vitamin D. The variable trust in specialized shops source remained consistently significant even when the sample was further reduced to the over-70s sub-group. All other variables considered were not statistically

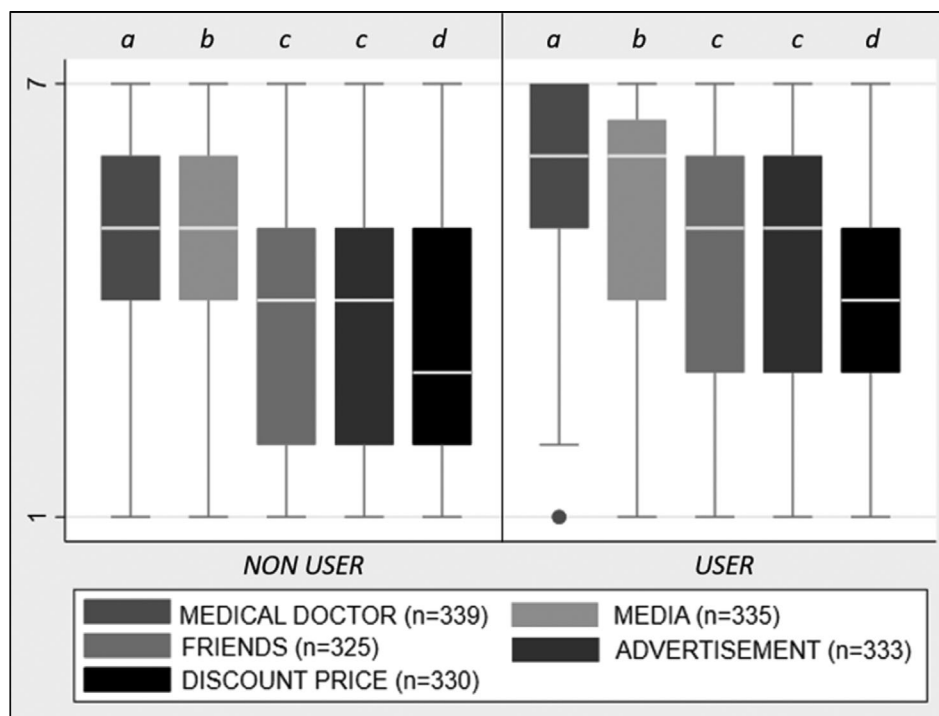


Figure 3. Box plot of vitamin D supplements purchasing likelihood scores for each vignette, divided into user/non-user. Different letters above the box plots shows significant differences in ANOVA post-hoc pairwise tests conducted within each subgroup.

significant ($P > 0.10$) in increasing the likelihood that the vulnerable target purchased vitamin D supplements.

DISCUSSION

The aim of the current study was to profile senior Danish citizens who are non-users of vitamin D supplements and to identify possible drivers to encouraging their purchase among this

vulnerable segment. Public health actions have been designed in recent years to urge the intake of vitamin D supplements that can support the elderly in achieving adequate vitamin D provision such as dedicated recommendations on the specific amounts to be supplemented. Identifying the most trusted sources for disseminating recommendations and barriers to vitamin D supplementation may be an optimal strategy to address the lack of health behaviour.

Table 4. Individual characteristics impacting vitamin D supplements purchasing likelihood

Parameter	Non-user ($n = 264$)		Non-user over 70 ($n = 95$)	
	(with participants' characteristics)		(with participants' characteristics)	
Vitamin D concern	0.218*** (0.071)	0.231*** (0.071)	0.169 (0.127)	0.156 (0.125)
Negative attitude	0.026 (0.081)	0.027 (0.083)	-0.046 (0.140)	-0.051 (0.136)
Trust in specialist shop	0.239*** (0.081)	0.250*** (0.082)	0.308** (0.144)	0.310** (0.142)
Trust in media	0.170** (0.080)	0.134* (0.080)	0.244 (0.148)	0.164 (0.145)
Trust in public health	0.199** (0.079)	0.227*** (0.080)	0.159 (0.143)	0.173 (0.143)
Sex	0.478*** (0.163)		0.595* (0.329)	
Education	0.183 (0.159)		0.115 (0.295)	
Marital status	-0.031 (0.173)		-0.069 (0.337)	
Subjective health	-0.003 (0.099)		0.228 (0.210)	
Weight perception	0.084 (0.141)		0.393 (0.291)	
Age	0.028*** (0.001)			
Constant	1.36 (0.872)	3.72*** (0.157)	-1.51 (2.87)	4.06*** (0.282)
R^2	0.20	0.13	0.21	0.12
F	5.56***	7.61***	2.04**	2.74***

Note: Multiple regression parameter estimates (with standard deviation in parentheses) for the 'Non-user' and 'Non-user over 70 years old' subgroup. The dependent variable is the probability of purchasing vitamin D supplements. Bold data are statistically significant at least at 0.1. Asterisks represent statistical significance at *** $P < 0.01$, ** $P < 0.05$ and * $P < 0.1$, respectively.

Results showed that approximately 50% of the respondents already reported using vitamin D supplements – mainly women, concerned about their health status and with a positive attitude towards the usefulness of supplements. By contrast, the senior citizens that reported not consuming vitamin D supplements perceived themselves to be healthy. The binomial ‘feel healthy–non-user’ might also be motivated by the lack of effective knowledge of one’s own serum vitamin D level. As reported by Tsalis *et al.*,²² for example, only 17% of the Danish general population (over 18 years) reported being aware of their personal vitamin D level. Adding to this, in line with other studies, is distrust about the usefulness of supplements. For example, the older adults interviewed in a large study conducted in the USA²³ believed that a ‘balanced diet’ already provided adequate vitamin D.²⁴ It follows that senior citizens must become more aware of their serum vitamin D levels so that they can monitor and act preventatively on the inevitable consequences associated with age. Health care specifically could make serum vitamin D level checks during routine medical check-ups mandatory (and not only on request) for the entire Danish population in general and the elderly in particular. Further, potential interventions should develop guidelines that clearly identify how an adequate level of vitamin D intake can be achieved. Messages aimed to shift the elderly’s beliefs should emphasize the positive aspects (that vitamin D supplements are good complements to the daily diet and reduce the likelihood of vitamin D deficiency and osteoporosis). Simultaneously, messages should de-emphasize the negative beliefs, such as using vitamin D supplements is not natural or that they may result in getting too much vitamin D.²⁵

Our results suggest that communication strategies to disseminate guidelines, specifically targeted at older people, would be more effective if doctors and the media were involved in the dissemination. In the case of non-users, the trust placed in the medical doctor is the most likely scenario for selecting supplements. Other studies have identified the family doctor as the primary and preferred source of information for the elderly,^{24–26} to the point that their suggestion to use vitamin D supplements is significantly associated with both higher supplement use and better vitamin D status. In Mortensen *et al.*’s²⁷ study on barriers to vitamin D supplement recommendations in Danish nursing homes, lack of prescription by the general physician was identified as a high determinant of low adherence to recommendations. Future research could explore what is behind doctors’ reluctance to prescribe vitamin D to senior citizens and what kind of dissemination strategy applied by medical doctors would be the most effective and easily implemented for increasing the use of vitamin D supplements. However, in a study among patients of general practice in England, the decision to take supplements was influenced more by family and friends than by doctors.²⁸ In our case, however, friends – as well as different inputs during shopping – have a significantly lower influence in persuading non-users to buy supplements, while investing in advertising campaigns in the media could be a useful alternative.

Referring to the elements of the HBM model, in our study we framed the probability of adopting health-related behaviour (taking vitamin D supplements) with different action cues (vignettes). This allowed us to identify possible ‘leverage points’ on which we could embroider effective strategies to improve non-users’ health behaviour. Among the variables included in the original model, only the perceived threat was statistically significant in increasing the likelihood of purchasing vitamin D supplements among non-users; thus, an increased concern about not getting enough vitamin D prompts the elderly to evaluate supplements positively in

solicited situations. In line with our results, similar outputs were found in the study of Engels *et al.*²⁵ among the elderly conducted in the Netherlands, in which perceiving a high risk of being vitamin D deficient was positively associated with the intention to start or restart vitamin D supplementation. Future interventions should include strategies to increase expectations of supplementation’s efficacy in balancing the messages of preventing vitamin D deficiency by dismissing the concern of taking ‘too much’.

In the current study, the other variables that are significant and positively associated with taking supplements among non-users are those related to the trust placed in the various sources of information. The greater the trust senior citizens have in the various sources of communication disseminating the recommendations, the greater the likelihood of choosing to take supplements. These findings suggest that increasing the trustworthiness of the sources of information may help the target group to increase their adherence and adopt healthy behaviours. In particular, for the over-70s, appealing to the trust placed in specialized shops provides an opportunity to communicate vitamin D supplement recommendations. Stands, promotions, leaflets or other advertising tactics in specialized retailers might be good options to consider.

Other studies aimed to investigate the determinants of supplement use were either not conducted on older people^{29,30} or applied different theoretical concepts²⁵ and therefore results are not directly comparable. There are certain limitations to this research that could affect the results and their generalizability. First, our results depend on self-reported data, which is commonly impacted by the gap between stated and actual behaviour. While the applied methodology makes our study original and unobtrusive in exploring potentially effective ‘nudges’ to increase vitamin D intake among the elderly, we cannot monitor actual behaviours or changes occurring over time.^{12,31–34} Despite the representative sample, another limitation of this study concerns the computer skills and nutrition literacy required by elderly respondents to complete the survey; this discrepancy from the rest of the target population may impact the external validity of our results. Furthermore, conducting the survey in September could potentially have had an impact on the results in terms of respondents’ underestimating the usefulness of vitamin D intake due to the relatively high number of hours of light at this time of the year compared to the winter. Moreover, this research was carried out in Denmark and thus the obtained findings cannot be generalized to other countries and cultures. Future research could investigate whether senior citizens in other countries also behave similarly provided with these same stimuli, and possibly add evaluations concerning the taste of supplements and how sensory acceptance may influence their intake.^{35,36}

CONCLUSIONS

Several public interventions have been designed in recent years to urge the intake of vitamin D supplements among the elderly population to avoid the direct and indirect consequences associated with low vitamin D status and vitamin D deficiency. However, the effectiveness of these public campaigns remains rather limited. Through an online survey involving a representative sample of senior citizens in Denmark, the present study first outlined the profile of elderly Danes who are non-users of vitamin D supplements and then investigated which strategies can support public health in promoting recommendations. Additionally, the potential drivers and barriers in implementing the desired health behaviour by the most at-risk segment (with reference to HBM)

were detected. About half of the sample reported that they had not taken vitamin D supplements in the previous year. The likelihood of being a non-user increased among males, seniors with a high positive perception of their health status and those with high scepticism towards the usefulness of vitamin D supplementation. The role of medical doctors (and secondarily the media) in promoting the adoption of supplement use seems crucial, but this may be more efficient when combined with availability and salience of messages in connection with products in specialized stores and supermarkets. Specifically, advertisements, stands and promotions seem a practical and attractive solution to increase the intake of vitamin D supplements for the over-70s who are not currently users.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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APPENDIX

Details of the vignettes applied in the online survey.

Discount price

Johan/Johanne, who is about your age, is on his/her weekly shopping trip around the supermarket. He/she looks for the good deals and eagerly flips through the special offers magazine, checking and comparing prices. He/she has reached the vitamin pill shelf. Johan/Johanne wasn't really planning to buy vitamin D supplements, but he/she sees that this week they are running a special on vitamin D supplements in pill form – two bottles for the same price as one.

Advertisement

Jens/Kirsten, who is about your age, has planned a particular dish for dinner and needs a few extra ingredients to buy on the way home. On his/her way around the local supermarket, he/she happens to pass a stand where a display of vitamin pills catches his/her eye. A large sign hanging above the vitamin pills says: 'Vitamin D helps reduce the risk of falls, which can be a consequence of balance problems and muscle weakness. Falling is a risk factor for fractures in men and women aged 60 and over'.

Medical doctor

Carl/Katrine, who is the same age as you, is at the doctor's because over the last 2 weeks he/she has been feeling a bit more lethargic than usual, tired and unwell. Carl/Katrine thinks it would be best to get it checked out. The doctor says that now we will do some tests and try to find out what is wrong, but the doctor also says that in Denmark vitamin D is not produced through sun exposure during the winter months, and it is also difficult to get enough vitamin D through diet. The doctor advises him/her to buy a vitamin D supplement to take home and start taking it. The doctor puts a leaflet in Carl/Katrine's hand so that he/she can read more about it when he/she gets home.

Friends

Kristian/Susanne has invited a bunch of the old gang, all about your age, home for a nice evening. There's a card game going on, conversation is lively, and spirits are high. One of the friends has his phone lying on the table. The phone rings suddenly – it's an alarm. 'Time for my daily dose,' says the friend cheerfully, getting up and going into the kitchen. He/she takes some pills from a box, puts them in his/her mouth and washes them down with a glass of water. He/she comes

Table A2. Output of principal component analysis with orthogonal rotation

Item	Factor 1 Negative attitude	Factor 2 Positive attitude
If you take a vitamin D supplement, how likely is it that ...	C = 0.35	C = 0.64
... it can lead to too much vitamin D	0.808	-0.059
... there may be long-term risks of vitamin D intake that are not known	0.843	-0.068
... intake of other nutrients may be adversely affected	0.762	0.189
... it will increase your well-being	-0.004	0.896
... it can reduce the damage caused by an unhealthy diet	0.355	0.387
... it can prevent disease	-0.002	0.889

Note: The values represent the correlation between the items and generated factors (expressed by factor loading). C represents the cumulative variance explained by the corresponding factor. Bold data are the items that score higher than 0.6.

back smiling and explains, 'When you get to our age, it's almost a full-time job to keep fit and healthy, and my daily dose of vitamin D and calcium supplements helps with that.'

Media

It's Sunday afternoon and Per/Karen, who is about your age, is sitting with a cup of coffee and a newly purchased weekly magazine. The rain beats on the window, and he/she pulls his/her knitted cardigan tighter around him/her. The radio sings quietly in the background. The calm has settled. The radio news comes on and the first story is about the difficulty of getting vitamin D from the sun in winter. The program also talks about some of the symptoms – and as they seem familiar, Per/Karen turns on his computer and finds netdoktor.dk to investigate further. He/she finds a page about vitamin D deficiency and reads with interest – the symptoms match what he/she has been feeling for the past few weeks. It is recommended here that a vitamin D supplement be taken, as this should reduce the symptoms noticeably.

Table A1. Items of general level of concern (from Meyer *et al.*, 1990)²¹ and vitamin D scepticism (from Jahn *et al.*, 2019).¹⁹ Mean value, standard deviation and Cronbach's alpha of applied scales

		Mean	SD
General concern $\alpha = 0.93$	My worries overwhelm me.	2.07	1.44
	Many situations make me worry	2.48	1.58
	I know I should not worry about things, but I cannot help it	2.61	1.72
	I worry all the time	2.09	1.44
<i>Average range: from 1 (=not at all typical for me) to 7 (=very typical of me)</i>		2.31	1.41
Vitamin D scepticism $\alpha = 0.73$	In Denmark, we get enough vitamin D from the foods we eat	3.60	1.73
	If you think about vitamin D, the sun is more important than food intake	4.47	1.67
	The sun provides enough vitamin D in Denmark, even during the winter months	3.10	1.77
	If you eat fish as a main course twice a week and as a side dish several times a week, you get enough vitamin D	4.81	1.67
<i>Average range: from 1 (=strongly disagree) to 7 (=strongly agree)</i>		3.84	1.39

Table A3. Output of principal component analysis with orthogonal rotation

	Factor 1 Trust in specialist shop C = 0.24	Factor 2 Trust in media C = 0.48	Factor 3 Trust in public health C = 0.67
Pharmacy	0.417	-0.067	0.734
Doctor	0.015	0.068	0.847
Specialist shop	0.817	0.089	0.331
Public authorities	0.039	0.450	0.635
Health food shops	0.835	0.210	0.041
Supermarkets	0.759	0.378	-0.002
Friends	0.272	0.556	0.186
Internet	0.183	0.772	0.018
TV	0.174	0.815	0.159
Magazines and newspapers	0.420	0.660	-0.042

Note: The values represent the correlation between the items and generated factors (expressed by factor loading). C represents the cumulative variance explained by the corresponding factor. Bold data are the items that score higher than 0.6.

Table A4. Summary of variables collected

Variable	Description	Coding and variable type
Sex	Respondent sex at birth	Dummy: 1 = women, 0 = men
Age	Respondent age in years	Double coding: Continuous (identified as Age); Dummy for the three age groups considered (identified as <65 years, 65–69 years, >70 years)
Education	Highest educational level acquired	Dummy: 1 = graduate or higher; 0 = not graduated
Marital status	Respondent has a partner or husband/wife	Dummy: 1 = partner, 0 = single, divorced, widowed
Subjective health	Perceived general health status	Ordinal: 1 = bad to 4 = very good
Weight perception	Perceived weight class	Ordinal: 1 = underweight, 2 = normal weight, 3 = overweight
General concern scale	General level of concern of respondents	Continuous
Vitamin D concern	Concern on sufficient vitamin D intake	Continuous
Vitamin D scepticism	Scepticism toward vitamin D supplements	Continuous
Negative attitude	Factor score measuring unfavourable attitude towards vitamin D supplements	Continuous
Trust in specialist shop	Factor score measuring trust in specialist and health food shop	Continuous
Trust in media	Factor score measuring trust in friends, Internet and TV as a source of information for nutritional recommendations	Continuous
Trust in public health	Factor score measuring trust in the doctor and pharmacy as a source of information for nutritional recommendations	Continuous
Purchasing probability	How probable is it that the protagonist of the vignette will buy vitamin D supplements calculated as the mean value of the probability stated in each of the 5 vignettes	Continuous
Non-vitamin D user	Respondents not using vitamin D supplements	Dummy: 1 = non-user, 0 = user