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# Prevalence, knowledge, awareness, and attitudes towards dietary supplements among Bahraini adults: a cross-sectional study

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## Abstract

The usage of dietary supplements (DS) is a global trend that is likely influenced by sociodemographic variables and body weight status. Some individuals utilize supplements in the hopes that they may enhance their health and prevent illness. Main objective of this study is to assess knowledge and awareness about using DS among Bahraini adults. This cross-sectional study was conducted using snowball sampling method, in which an electronic self-administrative questionnaire was used to collect information from 582 eligible participants. Data about socio-demographic characteristics, anthropometric measurements, knowledge, awareness, and attitudes toward using DS was collected from each participant. Prevalence of DS use was high (59.3%) and most of users were females. Most DS users (87.5%) thought that DS are safe ( $P < 0.001$ ). The DS users were significantly more likely than non-users to believe that DS can prevent and treat chronic and communicable diseases, as well as the DS having side effects ( $P < 0.05$ ). The most frequently consumed DS were vitamin D (29.5%) and vitamin C (26.4%). The main purpose of using DS among the DS users was to treat nutrient deficiency and around 60% of them used DS based on physician's prescription. In conclusion, the using of DS was highly prevalent among younger adult females with normal body weight. The findings of this study emphasize the need for implementing public educational programs about safe and proper use of DS.

**Keywords** Dietary supplements, Prevalence, Knowledge, Awareness, Attitudes, Bahrain

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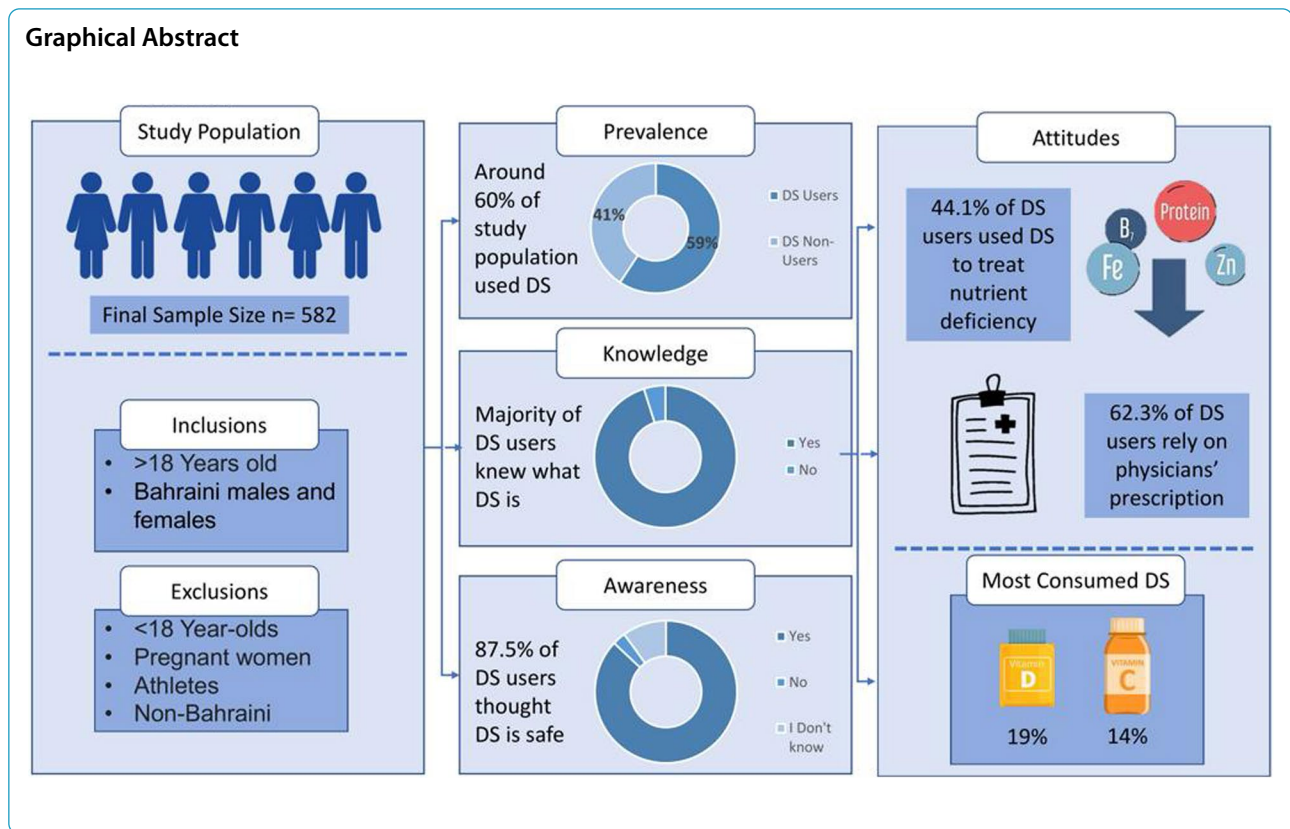
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## Introduction

A nutritious and well-balanced diet must contain all the essential nutrients that maintain the general health of individuals. However, dietary supplements (DS) have complementary roles, intended to help individuals in reaching their daily recommended dietary intakes (Alowais & Selim 2019; Valavanidis 2016). The Food and Drug Administration (FDA) defines DS as one or a combination of dietary substances such as vitamins, minerals, amino acids, and botanical herbs used by individuals to increase the total dietary intake for general health purposes. These DS are produced in specific dosages and multiple forms including capsules, tablets, powders, and liquids (FDA 2021). Since DS represent an important source of essential nutrients, they have vital roles in cellular processes including energy metabolism (i.e., as enzymes cofactors or structural components), as well as roles in cell growth and development (Huskisson et al. 2007a).

Regular diet should contain all the necessary nutrients, but there are individuals with specific nutritional needs that require DS intake such as those who have nutritional deficiencies, disorders of absorption, pregnant and lactating women as well as elderly people

(Alowais & Selim 2019; Huskisson et al. 2007a; Huskisson et al. 2007b). It is well established that dietary supplements can treat existing conditions of nutrient-deficiency diseases like scurvy, rickets, and pellagra require constant supplementation of vitamin C, vitamin D, and Vitamin B-3, respectively (Harsha et al. 2019; Holick 2006; Khalife et al. 2019).

Dietary supplements are not considered as drugs nor intended for use to prevent or treat diseases, with inconsistent evidence on their efficiency (Sirico et al. 2018). For an example, no significant effects were found upon regular consumption of vitamin C, vitamin E, and beta-carotene for the primary prevention of type 2 diabetes (Pathak et al. 2019). Also, the long-term intake of multivitamin supplementation was insufficient in reducing major cardiovascular events, myocardial infarction (MI), stroke, and cardiovascular disease (CVD) mortality (Sesso et al. 2012).

Recently, DS became one of the most increasing trends in the healthcare industry, playing a significant role in the global economy (Marcus 2016). One of the reasons for gaining more popularity is through advertising and marketing DS products in social media platforms, claiming for their safety and effectiveness. Another reason is the

increasing availability of DS in the markets, while it is not mandatory for sellers to conduct any research to prove the safety of these products (Bjelica et al. 2020). Thus, significant associations were found between relatively healthy and active individuals and the increased tendency to use DS (Sirico et al. 2018). For instance, studies conducted in Japan and Saudi Arabia have found increased prevalence of using DS among college students for health improvement purposes. These students have common beliefs that DS can improve general health, give physical strength, promote weight loss, and ensure adequate nutrition (Alowais & Selim 2019; Kobayashi et al. 2017).

DS users have limited knowledge about the adverse effects caused by DS (Alfawaz et al. 2017; Tangkiatkumjai et al. 2014). Many DS products may contain toxic or illegal ingredients such as 1,3-dimethylamylamine (DMAA). All products that contain DMAA are prohibited by FDA regulations (FDA 2022). Excessive intake of DS can also be harmful and cause severe complications (Genaro & Martini 2004). A toxicity report was made about pyridoxine overdose due to daily use of multivitamin supplements in two men aged 60 and 65 years (de Kruijk & Notermans 2005). Excessive pyridoxine intake generates neuropathy through the preferential injury of sensory neurons (Hadtstein & Vrolijk 2021). Another case reported adverse events of consuming black cohosh herbal supplement in menopausal women (Enbom et al. 2014).

Many studies were conducted in different countries, for example in Italy (Giammarioli et al. 2013), Korea (Yi et al. 2009), United States (Li et al. 2020), and Saudi Arabia (Samreen et al. 2020) to assess the population's knowledge, attitudes, and estimate the prevalence of using DS. And to our best knowledge, there are no studies that determine the prevalence of DS use in Bahrain. Therefore, the objectives of the current study were to determine the prevalence of DS use among Bahraini adults and to explore their knowledge and awareness towards using DS. The study also aimed to investigate the associations between DS intake and sociodemographic and health characteristics.

## Materials and methods

### Study design, sampling method and eligibility of participants

This cross-sectional study was conducted from 1<sup>st</sup> November to 20<sup>th</sup> November 2021. The snowball sampling method was used to enroll the study participants via a variety of social media channels (i.e., WhatsApp, Instagram, Snapchat, and Twitter). The study investigators invited eligible participants who expressed a desire to take part in the study to complete an online

self-administered questionnaire. Bahraini males and females aged 18 years and above, who are willing to give informed consent were eligible for participation in this study. Body builders, athletes, pregnant and lactating women, individuals with deficiency related disease (i.e., celiac disease, Crohn's disease, cystic fibrosis, and renal disease) or individuals with a history of gastric bypass, and who are younger than 18 were excluded from this study.

### Sample size

The required sample size was calculated using Raosoft sample size calculator ([http://www.raosoft.com/sample\\_size.html](http://www.raosoft.com/sample_size.html)) at 95% confidence level and 5% pre-determined margin of error with 50% response distribution for each question. The minimum required sample size of this study was 385.

### Data collection tools

An online self-administered questionnaire (Google forms) was developed from validated Knowledge, Attitudes and Practices (KAP) questionnaire (Alhormoud et al. 2016) and relevant published questionnaires (Basheer et al. 2021; Samreen et al. 2020; Sirico et al. 2018). The developed questionnaire was piloted and pretested among 30 individuals. The socio-demographic information of participants was collected in the first section. Participant's knowledge, awareness, and attitude related to DS were evaluated in the second section. Questions of the developed survey were available in native Arabic language as well as in English language. The questionnaire took an average of 20 min to complete.

### Socio-demographic data

Socio-demographic information was acquired on gender, nationality, age, education level, occupation, monthly income, smoking, and health status.

### Anthropometric measurements of participants

The participants were asked to record their current weight in kilograms (kg) and height in centimeter (cm). Body Mass Index (BMI) was calculated as weight in kg divided by height in meters squared and was classified in accordance with WHO guidelines (WHO, 2002).

### Knowledge and awareness about using dietary supplements

This section included five questions, two questions for knowledge, and three questions for awareness. Four of these questions were trichotomous. The responses to the questions were yes/no/I do not know. Participants were also asked to give their responses about the source that

is considered the most reliable for information about DS. This question had five responses: 1) family and/or friends, 2) physicians, healthcare providers, 3) TV or journal advertisements, 4) internet social media, 5) other and each participant could have multiple responses to this question. These evaluations were studied in relation to DS usage, age, and BMI. Awareness was evaluated by asking about safety of using DS, and role of DS in preventing and/or treating chronic diseases as well as communicable diseases.

#### **Attitudes toward using dietary supplements**

Participants were asked to confirm if they have used DS during the last six months to consider them as DS users. Non-users were participants never used DS during the last six months. Users were requested to choose the types of used supplements, intake frequency in addition to the reasons. They were allowed to choose more than one answer and state additional options if needed. Other requirements to determine users' attitudes included the followed prescription method, confirming benefits with risks of using DS and recommendations according to everyone's experience.

#### **Statistical analysis**

Statistical analysis was performed by Statistical Package for the Social Sciences (SPSS) version 26 (IBM Corporation, Armonk, NY, USA). Frequencies and percentages were calculated to describe categorical variables (socio-demographic data, participant's knowledge and awareness about DS, and participant's attitude regarding DS). Median and interquartile range were calculated for the continuous variables (age, weight, height, and BMI). *Pearson's Chi-square* test was used to detect significant differences between use of DS, age, and BMI, and the corresponding questions of knowledge and awareness toward DS. Associations between demographic characteristics, body weight and health status, and use of DS were calculated by multinomial logistic regression where the significance level was set at  $P < 0.05$ . A linear logistic regression model was used to calculate  $P$ -value for trend.

#### **Ethical approval and research consent**

The study protocol was conformed to the ethical guidelines of the 1975 Declaration of Helsinki, and the study was approved by ethics committee at the Department of Biology, College of Science, University of Bahrain.

All participants were requested to approve on the informed consent prior to their participation. Participants were not forced if they refused to participate in this survey. Upon data collection, no names, phone numbers or identification numbers were collected from

participants to maintain their privacy, but IP-addresses were collected. Financial incentives were not offered for any individual upon his/her participation.

## **Results**

### **Socio-demographic characteristics of study sample**

Overall, a total of 603 responses participated voluntarily in this study. Only 21 participants were excluded because 15 were non-Bahraini, 2 were under 18 years old, 3 were pregnant women, and 1 was an athlete participant (Fig. 1). Socio-demographic characteristics of 582 participants are presented in Table 1. Majority of participants were Bahraini females, achieving an approximate percentage of (70.3%). In addition, the median age of participants was (23 years) and BMI (24.8 kg/m<sup>2</sup>). Around half of participants were normal body weight (43.2%) and fourth of them were overweight (26.3%). Nearly half of participants were students (45.9%) and Bachelor degree holders (51.7%). Regarding health-related factors, there were only (22%) of participants having chronic diseases. A small number of participants were current smokers (17%).

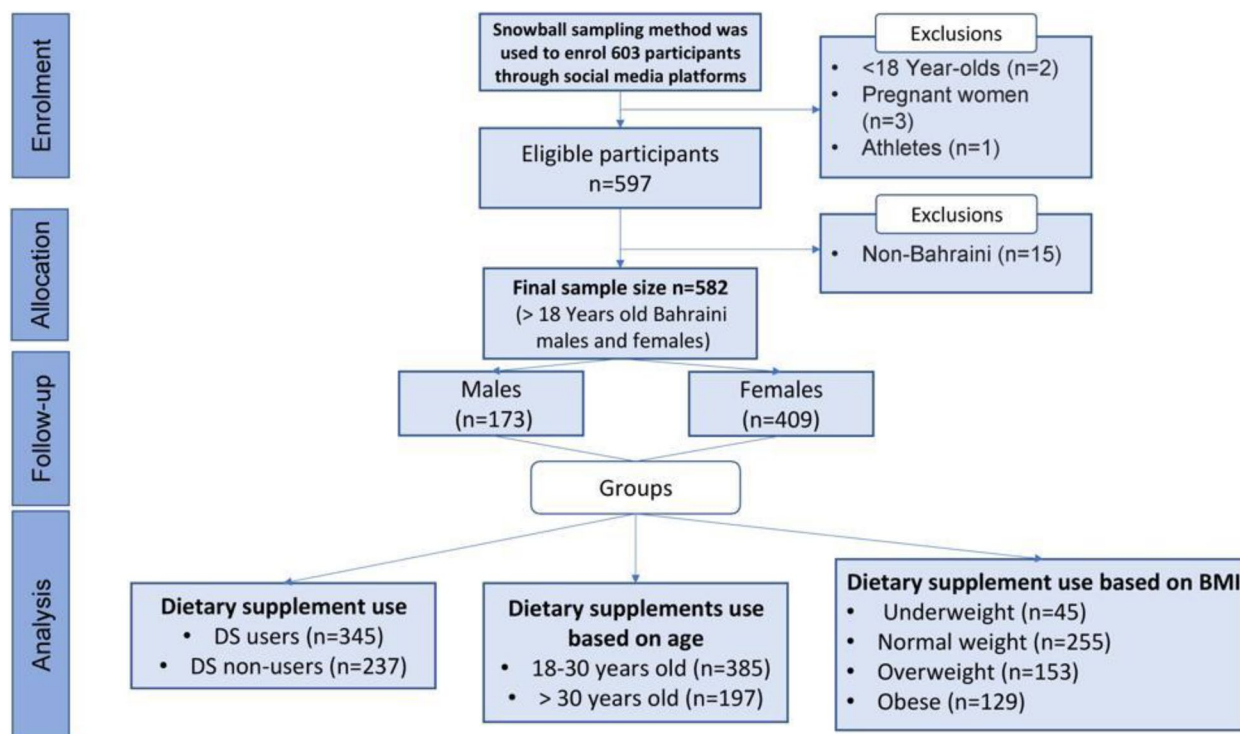
### **Types of the most commonly used dietary supplements among the study population**

Figure 2 shows the most used DS by DS users. Vitamin D (29.5%), vitamin C (26.4%), and iron (17.7%) were the most prevalent used DSs. In contrast, folic acid (8.7%) and vitamin B complex (8.1%) supplements were less frequently consumed.

### **Knowledge and awareness of participants about dietary supplements**

Table 2 shows the knowledge and awareness of DS users and non-users. About 60% of the study participants used DS. The DS users (95.1%) were significantly more likely than non-users (72.6%) in knowing DS ( $P < 0.001$ ). Both DS users and non-users used internet and/or social media to seek information about DS ( $P = 0.936$ ). There was no significant difference between DS users and non-users in getting information from physicians and health-care providers ( $P = 0.054$ ). A large proportion of DS users (87.5%) believed that DS are safe. Furthermore, DS users believed significantly more in the role of DS in preventing and managing chronic and communicable diseases ( $P < 0.01$ ). Regarding possible side effects of DS, approximately half of DS users and non-users believed that DS might have side effects. However, (21.7%) of users versus (34.6%) of non-users were not sure about DS side effects ( $P = 0.001$ ).

Table 3 shows DS knowledge and awareness based on age of the study participants. The percentage of participants who knew DS was significantly higher among younger participants who aged between 18 and 30 years compared to older participants who aged more than



**Fig. 1** Flow diagram of participants enrollment

30 years ( $P < 0.001$ ). High proportion of younger (71.9%) and older (68.5%) participants used internet and/or social media to find information about DS. Older participants were significantly more likely to get information about DS from physicians and health-care providers than younger participants ( $P = 0.005$ ). There were no significant differences between younger and older participants regarding their awareness about the DS safety and the role of DS in preventing and managing chronic diseases. For example, (46.2%) of older participants believed that DS could prevent and manage communicable diseases ( $P = 0.02$ ). A significant difference was detected between younger (62.6%) and older (44.7%) participants in the probability of DS to have side effects ( $P < 0.001$ ).

No significant differences were found in knowledge, source of information, prevention or treatment of chronic and communicable diseases, and DS side effects based on body weight status in Table 4. The proportion of participants who believed that DS is safe was significantly lower in obese (62.8%) compared to underweight (73.3%), normal body weight (81.2%), and overweight (76.5%) ( $P = 0.01$ ).

#### Associations of socio-demographic characteristics with dietary supplements usage

The associations between socio-demographic characteristics, health status and the use of DS are given in Table 5.

The multinomial logistic regression analysis showed that being female and well-educated were associated with increased folds of using DS OR 2.13, 95% CI (1.49–3.05) ( $P < 0.001$ ), OR 1.69, 95% CI (1.22–2.36) ( $P = 0.002$ ), respectively. Likewise, high monthly income and having chronic disease were positively associated with using of DS OR 2.66, 95% CI (1.18–6.0) ( $P = 0.033$ ), OR 1.78, 95% CI (1.17–2.70) ( $P = 0.006$ ), respectively.

#### The attitudes, habits and awareness of dietary supplement users

Table 6 presents user's attitudes, habits, and awareness towards DS. Around 44% of DS users used DS to treat nutrient deficiency followed by 19.4%, 8.7%, 7.0%, 7.0%, 6.7%, 5.5%, and 1.7% who used DS for general health and well-being, boosting immunity by prevention from communicable diseases, weight loss or gain purposes, energy source, beauty purpose, preventing or treating a chronic disease, and elevating allergies and their related symptoms, respectively. Half of DS users took DS on daily basis (50.3%). Physicians' prescription was the most common approach by DS users for DS intake (62.3%). Minor of DS users (14.7%) experienced side effects related to DS intake. The most commonly reported side effect was weight gain, excessive hair growth, dizziness, headache and stool discoloration (5.9%) followed by constipation

**Table 1** Socio-demographic characteristics of participants

Variable	Participants (N = 582)
<b>Gender</b>	<b>n (%)</b>
Male	173(29.7)
Female	409(70.3)
<b>Age and Anthropometric measurements</b>	<b>Median (25th-75th percentile)</b>
Age (years)	23.0(21.0–37.0)
Height (cm)	163.0(157.0–169.9)
Weight (kg)	67.0(55.4–80.0)
BMI (kg/m <sup>2</sup> )	24.8 (21.4–29.4)
<b>BMI category</b>	<b>n (%)</b>
Underweight	45(7.7)
Normal body weight	255(43.8)
Overweight	153(26.3)
Obese	129(22.2)
<b>Sociodemographic characteristics</b>	<b>n (%)</b>
<b>Monthly Income</b>	
Less than 500 BD	441 (75.8)
From 500 to 1000 BD	107(17.9)
More than 1000 BD	34(6.3)
<b>Educational Level</b>	
Secondary school degree or less	194 (33.3)
Diploma degree	78(13.4)
Bachelor's degree	301(51.7)
Master's degree and above	9(1.5)
<b>Occupational</b>	
Student	267 (45.9)
Employee	156(26.8)
Housewife	89(15.3)
Unemployed	70(12.0)
<b>General health-related factors</b>	<b>n (%)</b>
<b>Presence of Chronic Disease</b>	
Yes	128 (22.0)
No	454(78.0)
<b>Smokin</b>	
Non-smoker	337(57.9)
Passive smoker	146(25.1)
Current smoker	99(17.0)
<b>Type of current Smoking</b>	
Cigarettes/ Electronic Cigarettes	66(51.2)
Hookah/ Electronic Hookah	63(48.8)

(5.6%). The majority of DS users (81.4%) stated they would recommend their families and friends to use DS.

## Discussion

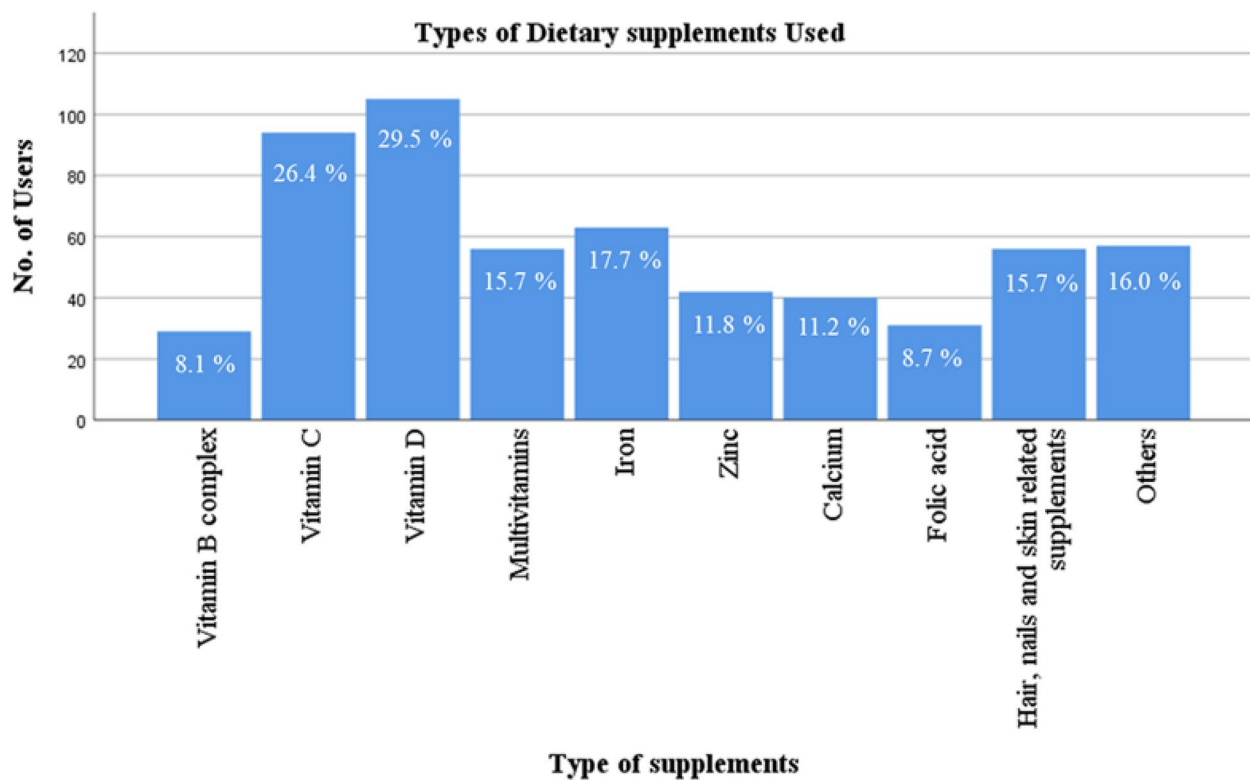
To our best knowledge, the current study is the first to investigate knowledge, awareness, and attitudes of using DS among small population in kingdom of Bahrain.

Several studies have been conducted about the use of DS in the Gulf region including countries such as Kuwait (Awad and Al-Shaye et al. 2014), United Arab Emirates (Abdulla et al. 2019), and Qatar (Mamtani et al. 2015) but none in Bahrain. In our findings, more than half of participants (59.6%) have used DS. This result is consistent with the findings in Jordan where the prevalence of DS use was 62% among Jordanian adults (Basheer et al. 2021). Whereas study conducted in Dubai showed that 37.8% of participants used DS (Abdulla et al. 2019). The prevalence of DS use is different among studies and may be attributed to certain factors like study method, type of respondents, and demographic characteristics of participants (Samreen et al. 2020).

The most prevalently used dietary supplements were vitamin D, vitamin C, and iron. Studies in Jordan (Basheer et al. 2021) and Saudi Arabia (Abdel-Salam et al. 2020) indicated that vitamin D was the most common used DS. Many studies conducted in Jordan (Basheer et al. 2021), Canada (Shakur et al. 2012), and Malaysia (Abd Wahab et al. 2021) revealed that vitamin C was the most frequent used DS. It should be noted that the high percentage of using vitamin D is due to the common issue of vitamin D deficiency in Bahrain (Sanad et al. 2020). The increase in using vitamin C is probably because of the widespread beliefs about its ability to boost immunity and relieve cold symptoms, especially during the flu season and Covid-19 pandemic. However, available data about their high efficiency is scarce (Cerullo et al. 2020). According to a systematic analysis of 31 studies that looked at the impact of regular vitamin C on cold duration. The duration of colds decreased by 14% (7% to 21%) in children and by 8% (3% to 12%) in adults, and the frequent intake of vitamin C also lessened the severity of colds (Hemilä & Chalker 2013).

In agreement with other studies (Alowais & Selim 2019; Kobayashi et al. 2017), iron was mostly used by women, specifically during pregnancy to reduce the risk of iron deficiency anemia and other adverse outcomes.

The assessment of knowledge and awareness of participants was done based on the DS usage, age, and body weight status. The results indicated that the majority of participants knew about DS. Additionally, a large proportion of participants took their knowledge about DS from internet and/or social media which are not reliable and could have wrong or misleading information. DS can also be advertised for their safety but not for their potential side effects (Binns et al. 2018). These results are consistent with other studies which showed that social media platforms were the most common source of information about DS (Alfawaz et al. 2017; Basheer et al. 2021).



**Fig. 2** Most commonly used dietary supplements among study participants

Furthermore, participants highly agreed about the safety of DS intake although the awareness about using DS to prevent or treat chronic diseases was inconclusive. These results were expected because some individuals have different lifestyle habits, or they are less educated about the roles of DS. Only few studies had been conducted to investigate the ability of DS to reduce the risk of chronic diseases (Gaziano et al. 2012; Walrand 2018). In fact, the role of DS in preventing or treating chronic diseases such as cancer (Fortmann et al. 2013), diabetes (Seida et al. 2014), and cardiovascular complications (Moyer 2014) have been inconsistent. On the contrary, a study concluded that using calcium with or without vitamin D regularly can increase the risk of cardiovascular events (Bolland et al. 2011).

The results of this study found that participants are highly aware about the possibility of DS causing adverse effects. It is well established that some DS may have unlabeled, harmful, or toxic ingredients which may contribute to unwanted harm or increase the risk of suffering from chronic diseases (Samreen et al. 2020). This fact is in agreement with the current findings of DS users where only few users had side effects but more than half of them did not suffer from any adverse

effects. Therefore, individuals should always seek medical advice from physicians before using any DS to avoid potential harm.

The associations between DS use and socio-demographic characteristics were investigated in the current study. Gender, age, monthly income, educational level, and general health status were associated with using DS. In particular, being a young female was positively associated to the tendency to use DS. This may be due to the fact that females are more health conscious than males and their need for adequate nutrients increases during reproductive age. Females also used DS to improve general well-being (Radwan et al. 2019). This has been confirmed by the National Health and Nutrition Examination Surveys (NHANES) done in 2003–2006, as young women took DS more than men, 43% and 36%, respectively (Bailey et al., 2011). Similarly, higher educational levels and high financial status were associated with a higher frequency of DS intake and these results are in agreement with other studies (Alfawaz et al., 2017; Alowais & Selim, 2019; Cowan et al. 2018). A Korean study also observed the same results that well-educated women with high monthly income were more likely to use DS than men (Kim et al. 2010).

**Table 2** Knowledge and awareness of participants regarding dietary supplements use

Knowledge of DS	DS users (n = 345) (59.3%)	DS non-users (n = 237) (40.7%)	P-value
<b>Do you know what the dietary supplements are?</b>	n(%)	n(%)	
Yes	328(95.1)	172(72.6)	< 0.001
No	17(4.9)	65(27.4)	
I don't know	0	0	
<b>Source of information<sup>a</sup></b>			
Family and/or friends	148(42.9)	85(35.9)	0.064
Physicians, healthcare providers	141(40.9)	116 (48.9)	0.054
TV	45(13.0)	35(14.8)	0.548
Internet and/or social media	243(70.4)	169(71.3)	0.936
Other	14(4.1)	7(3.0)	0.322
<b>Awareness</b>			
<b>Do you think the use of nutritional supplements is always safe?</b>			
Yes	302(87.5)	136(57.4)	< 0.001
No	9(2.6)	17(7.2)	
I don't know	34(9.9)	84(35.4)	
<b>Do you think that dietary supplements can prevent or treat chronic diseases?</b>			
Yes	162(47.0)	82(34.6)	0.001
No	109(31.6)	74(31.2)	
I don't know	74(21.4)	81(34.2)	
<b>Do you think that dietary supplements can prevent or treat communicable diseases?</b>			
Yes	172(49.9)	77(32.5)	< 0.001
No	109(31.6)	79(33.3)	
I don't know	64(18.6)	81(34.2)	
<b>Do you think that the dietary supplements have side effects?</b>			
Yes	205(59.4)	124(52.3)	0.001
No	65(18.8)	31(13.1)	
I don't know	75(21.7)	82(34.6)	

<sup>a</sup> Multiple response is possible

This study also showed that participants suffering from chronic diseases were positively associated with DS intake as they are probably more concern about their health status than those without any conditions and have greater awareness, allowing them to obtain treatments for their conditions. Since chronic diseases are age-related, several studies have observed the relationship between aging with DS use. Indeed, a study carried out in California, USA showed that adults with cancer or other chronic conditions had higher prevalence of supplement use than individuals reporting no illness (Miller et al. 2008). Another study conducted among elderly patients in Japan detected a regular use of non-prescribed drugs with vitamins being the most prevalent (Masumoto et al. 2018).

**Table 3** Knowledge and awareness of participants regarding dietary supplement use based on age

Knowledge of DS	18–30 years old (n = 385)	> 30 years old (n = 197)	P-value
<b>Do you know what dietary supplements are?</b>	n(%)	n(%)	
Yes	339(88.1)	161(81.7)	0.035
No	46(11.9)	36(18.3)	
I don't know	0	0	
<b>Source of information<sup>a</sup></b>			
Family and/or friends	155(40.3)	78(39.6)	0.887
Physicians, healthcare providers	153(39.7)	104(52.8)	0.005
TV	52(13.5)	28(14.2)	0.989
Internet and/or Social Media	277(71.9)	135(68.5)	0.330
Other	10(2.6)	11(5.6)	0.055
<b>Awareness</b>			
<b>Do you think the use of nutritional supplements is always safe?</b>			
Yes	295(76.6)	143(72.6)	0.19
No	13(3.4)	13(6.6)	
I don't know	77(20.0)	41(20.8)	
<b>Do you think that dietary supplements can prevent or treat chronic diseases?</b>			
Yes	148(38.4)	96(48.7)	0.32
No	132(34.3)	51(25.9)	
I don't know	105(27.3)	50(25.4)	
<b>Do you think that dietary supplements can prevent or treat communicable diseases?</b>			
Yes	158(41.0)	91(46.2)	0.02
No	139(36.1)	49(24.9)	
I don't know	88(22.9)	57(28.9)	
<b>Do you think that the dietary supplements have side effects?</b>			
Yes	241(62.6)	88(44.7)	< 0.001
No	60(15.6)	36(18.3)	
I don't know	84(21.8)	73(37.1)	

<sup>a</sup> Multiple response is possible

Normal body weight and overweight individuals were more likely to use DS than obese individuals. These results agree with the NHANES 2003–2006 findings that revealed obese participants took fewer dietary supplements (48%) than overweight (57%) or normal-weight participants (56%) (Bailey et al. 2011). No significant association was observed between smoking and DS intake in the current study. Numerous studies showed that the use of DS was associated with former smokers (Knudsen et al. 2002; Kim et al. 2010; Abdulla et al. 2019).

In regard to DS users' habits, the main reasons for taking DS were to treat nutrient deficiency or for general health and wellbeing. These reasons are convenient with users interests to improve general health and shown to



**Table 4** Knowledge and awareness of participants regarding dietary supplement use based on body weight status

Knowledge of DS	Underweight (n = 45)	Normal weight (n = 255)	Overweight (n = 153)	Obese (n = 129)	P-value
<b>Do you know what are dietary supplements?</b>	n(%)	n(%)	n(%)	n(%)	
Yes	40(88.9)	219(85.9)	136(88.9)	105(81.4)	0.26
No	5(11.1)	36(14.1)	17(11.1)	24(18.6)	
I don't know	0	0	0	0	
<b>Source of information<sup>a</sup></b>					
Family and/or friends	18(40.0)	105(41.2)	71(46.4)	63(48.8)	0.64
Physicians, healthcare providers	18(39.1)	110(41.7)	71(45.8)	65(49.2)	0.44
TV	7(15.6)	32(12.5)	22(14.4)	19(14.7)	0.93
Internet and/or social media	32(71.1)	175(68.6)	101(66.0)	104(80.6)	0.06
Other	1(2.2)	9(3.5)	5(3.3)	6(4.7)	0.86
<b>Awareness</b>					
<b>Do you think the use of nutritional supplements is always safe?</b>					
Yes	33(73.3)	207(81.2)	117(76.5)	81(62.8)	0.01
No	1(2.2)	9(3.5)	6(3.9)	10(7.6)	
I don't know	11(24.4)	39(15.3)	30(19.6)	38(29.5)	
<b>Do you think that dietary supplements can prevent or treat chronic diseases?</b>					
Yes	16(35.6)	116(45.5)	67(43.8)	45(34.9)	0.28
No	16(35.6)	79(31.0)	41(26.8)	47(36.4)	
I don't know	13(28.9)	60(23.5)	45(29.4)	37(28.7)	
<b>Do you think that dietary supplements can prevent or treat communicable diseases?</b>					
Yes	17(37.8)	114(44.7)	66(43.1)	52(40.3)	0.52
No	18(40.0)	84(32.9)	45(29.4)	41(31.8)	
I don't know	10(22.2)	57(22.4)	42(27.5)	36(27.9)	
<b>Do you think that the dietary supplements have side effects?</b>					
Yes	30(66.7)	153(60.0)	76(49.7)	70(54.3)	0.14
No	7(15.6)	35(13.7)	26(17.0)	28(21.7)	
I don't know	8(17.8)	67(26.3)	51(33.3)	31(24.0)	

<sup>a</sup> Multiple response is possible

be true by other studies as their benefits are well documented (Kobayashi et al. 2017; Valavanidis 2016). More than half of DS users were taking DS based on physician's prescription which indicates their awareness about not initiating the use of DS without medical recommendations. A more recent cross-sectional study conducted in Dubai reported only 46.6% of participants were prescribed healthy supplements (Abdulla et al. 2019). However, contradictory finding was reported in Jordanian study in which self-prescription was the most popular way by DS users for supplement intake (Basheer et al. 2021).

The majority of DS users recommended everyone to use DS according to their experiences, since they found that DS are mostly safe. In contrast there was only 36.4% of Saudi pharmacy students would always recommend

the use of DS (Samreen et al. 2020). The current evidence of this study in relation to participants beliefs, general public must be always encouraged following physicians' advices and seeking knowledge from reliable sources.

This study had some limitations. Firstly, the cross-sectional design which only provides minimal information about beliefs of participants at the time of the study and the cross-sectional design is not appropriate to assess causality. Secondly, the sample size was small which did not represent overall Bahrain's population. Thirdly, the used questionnaire in the current study was not validated. Fourthly, no information was collected about the daily nutritional habits, type of chronic diseases, physical activity of participants that would provide more detailed evaluation on general health status related to DS use. Fifthly, the study findings being self-reported by

**Table 5** Association between socio-demographic characteristics and health status and using of dietary supplements

Variables	Number of participants	Odd ratio 95% confidence interval	P-trend value*
<b>Gender</b>			
Male	173	1	< 0.001
Female	409	2.13(1.49–3.05)	
<b>Age</b>			
18–30 years	385	1	0.208
> 30 years	197	1.25(0.88–1.78)	
<b>Educational level</b>			
Not well- educated (Secondary school degree or less)	194	1	0.002
Well educated (Diploma degree or higher)	388	1.69(1.22–2.36)	
<b>Occupation</b>			
Non-employed (Student, house-wife, and unemployed)	426	1	0.100
Employed	156	1.37 (0.94–1.99)	
<b>Monthly income</b>			
Less than 500 BD	441	1	0.033
From 500 to 1000 BD	107	1.12(0.73–1.74)	
More than 1000 BD	34	2.66(1.18–6.0)	
<b>Smoking</b>			
Non-smoker	337	1	0.322
Smoker	245	0.82(0.56–1.21)	
<b>Presence of chronic disease</b>			
No	454	1	0.006
Yes	128	1.78(1.17–2.70)	
<b>BMI</b>			
Underweight	45	1.42(0.72–2.80)	0.05
Normal weight	255	1.72(1.18–2.68)	
Overweight	153	1.63(1.03–2.61)	
Obese	129	1	

Data is shown as crude odds ratio (95% CI) calculated by multinomial logistic regression

\* P-trend was calculated by linear regression and P value < 0.05 was considered statistically significant

the population could lead to a non-differential information bias, which could bias the results towards the null. Finally, the current study was conducted on young adults and results of this study cannot be generalized to the whole Bahraini society.

### Conclusion

This study determined the prevalence of DS using among small Bahraini population. The use of DS has shown to be highly prevalent among younger adult females with normal body weight. DS users seem aware of the reasons for

**Table 6** Habits and beliefs about using dietary supplements among users

Habits and beliefs about using DS	DS users (n = 345)
<b>- For what purpose would you use a dietary supplement product?</b>	
To treat a nutrient deficiency	152(44.1)
To prevent or treat a chronic disease	19(5.5)
To boost immunity by prevention from communicable diseases (e.g. flu/cold/ covid-19 virus)	30(8.7)
To elevate allergies and their related symptoms	6(1.7)
For general health and wellbeing	67(19.4)
Energy source	24(7.0)
Weight loss or gain purposes	24(7.0)
Beauty purpose	23(6.7)
<b>- How often do you take dietary supplements?</b>	
Daily	175(50.7)
Weekly	67(19.4)
Few times a week	45(13.0)
Monthly	38(11.0)
I don't use any supplement currently	20(5.8)
<b>- Are you taking supplements based on your Doctor's prescription or is it a self- prescription?</b>	
Based on physician's prescription	215(62.3)
Someone I know recommend it to me	34(9.9)
Self-prescription based on my own knowledge	96(27.8)
<b>- Have you ever experienced any side effect(s) while taking your supplements?</b>	
Yes	50(14.7)
No	226(66.3)
I don't know	69(20.0)
<b>- What type of side effects did you experience?</b>	
Constipation	20(5.6)
Upset stomach	7(2.0)
Insomnia	3(0.8)
Nausea	2(0.6)
Others (weight gain, excessive hair growth, dizziness, headache and stool discoloration)	21(5.9)
<b>- Do you recommend taking dietary supplements for everyone according to your experience?</b>	
Yes	281(81.4)
No	50(14.5)
I don't know	14(4.1)

taking DS by relying on physician's prescription. However, precautions are needed while using DS and individuals must be educated about benefits and hazards of DS and proper use of DS through implementing public educational programs.

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### Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by Ethics Committee at Department of Biology, College of Science, University of Bahrain, Kingdom of Bahrain.

### Authors' contributions

Conceptualization, S.A. and M.H.; methodology, M.H. and S.A.; software M.H., S.A. M.A. and S.P.; formal analysis M.H., S.A., D.M. M.A. and S.P.; investigation, M.H., S.A., D.M., and M.A.; resources, M.H., S.A., D.M., and M.A.; data curation, M.H. and S.A.; writing—original draft preparation, M.H. S.A., M.H., T. A., and R.T.; writing—review and editing, S.A. M.H., M.H., and R.T.; visualization, M.H. and S.A.; supervision, S.A. and R.T.; project administration, S.A. and M.H. All authors have read and agreed to the published version of the manuscript.

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### Ethics approval and Consent to participate

Informed consent was obtained from all subjects involved in the study.

### Competing interest

The authors declare no conflict of interest.

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### References

- Abd Wahab, M., Zaini, M. H., Ali, A. A., Sahudin, S., Mehat, M. Z., Hamid, H. A., Mustaffa, M. F., Othman, N., & Maniam, S. (2021). The use of herbal and dietary supplement among community-dwelling elderly in a suburban town of Malaysia. *BMC Complementary Medicine and Therapies*, 21, 110.
- Abdel-Salam, M. D., Alruwaili, M. J., Alshalan, A. R., Alruwaili, A. T., Alanazi, A. S., & Lotfy, M. M. A. (2020). Epidemiological aspects of dietary supplement use among Saudi medical students: A cross-sectional study. *The Open Public Health Journal*, 13, 783–790.
- Abdulla, N. M., Aziz, F., Blair, I., Grivna, M., Adam, B., & Loney, T. (2019). Prevalence of, and factors associated with health supplement use in Dubai, United Arab Emirates: a population-based cross-sectional study. *BMC Complementary and Alternative Medicine*, 19, 172.
- Alfawaz, H., Khan, N., Alfaiqi, A., Shahrani, F. M., Al-Tameem, H. M., Al-Otaibi, S. F., Abudigin, W. I., Al-Shayaa, M. S., Al-Ghanim, S. A., & Al-Daghri, N. M. (2017). Prevalence of dietary supplement use and associated factors among female college students in Saudi Arabia. *BMC Women's Health*, 17, 116.
- Alhomoud, F.K., Basil, M., & Bondarev, A. (2016). Knowledge, attitudes and practices (KAP) relating to dietary supplements among health sciences and non-health sciences students in one of the universities of United Arab Emirates (UAE). *J Clin Diagn Res*, 10, JC05-JC09.
- Alowais, M. A., & Selim, M. (2019). Knowledge, attitude, and practices regarding dietary supplements in Saudi Arabia. *Journal of Family Medicine and Primary Care*, 8, 365–372.
- Awad, A., & Al-Shaye, D. (2014). Public awareness, patterns of use and attitudes toward natural health products in Kuwait: A cross-sectional survey. *BMC Complementary and Alternative Medicine*, 14, 105.
- Bailey, R. L., Gahche, J. J., Lentino, C. V., Dwyer, J. T., Engel, J. S., Thomas, P. R., Betz, J. M., Sempos, C. T., & Picciano, M. F. (2011). Dietary supplement use in the United States, 2003–2006. *The Journal of Nutrition*, 141, 261–266.
- Basheer, A. H., Elsalem, L., Jaber, D., Ibraheem, M. S., Alhamad, H., & Jum'ah, A.A. (2021). Knowledge, awareness and practices regarding dietary supplements in Jordan. *Tropical Journal of Pharmaceutical Research*, 20, 649–659.
- Binns, W. C., Lee, K. M., & Lee, H. A. (2018). Problems and prospects: Public health regulation of dietary supplements. *Annual Review of Public Health*, 39, 403–420.
- Bjelica, A., Aleksić, S., Goločorbin-Kon, S., Szadanić, D., Torović, L., & Cvejić, J. (2020). Internet marketing of cardioprotective dietary supplements. *The Journal of Alternative and Complementary Medicine*, 26, 204–211.
- Bolland, M. J., Grey, A., Avenell, A., Gamble, G. D., & Reid, I. R. (2011). Calcium supplements with or without vitamin D and risk of cardiovascular events: Reanalysis of the women's health initiative limited access dataset and meta-analysis. *BMJ*, 342, d2040.
- Cerullo, G., Negro, M., Parimbelli, M., Pecoraro, M., Perna, S., Liguori, G., Rondanelli, M., Cena, H., & D'Antona, G. (2020). The long history of vitamin C: From prevention of the common cold to potential aid in the treatment of COVID-19. *Frontiers in Immunology*, 11, 574029.
- Cowan, A.E., Jun, S., Gahche, J.J., Toozé, J.A., Dwyer, J.T., Eicher-Miller, H.A., Bhadra, A., Guenther, P.M., Potischman, N., Dodd, K.W., & Bailey, R.L. (2018). Dietary supplement use differs by socioeconomic and health-related characteristics among U.S. adults, NHANES 2011–2014. *Nutrients*, 10, 1114.
- de Kruijk, J. R., & Notermans, N. C. (2005). Sensory disturbances caused by multivitamin preparations. *Nederlands Tijdschrift Voor Geneeskunde*, 149, 2541–2544.
- Enbom, E. T., Le, M. D., Oesterich, L., Rutgers, J., & French, S. W. (2014). Mechanism of Hepatotoxicity due to Black Cohosh (*Cimicifuga racemosa*): Histological, immunohistochemical and electron microscopy analysis of two liver biopsies with clinical correlation. *Experimental and Molecular Pathology*, 96, 279–283.
- Food and Drug Administration (FDA). Dietary supplement products & ingredients. Available online: <https://www.fda.gov/food/dietary-supplements/dietary-supplement-products-ingredients>. Accessed 13 Dec 2021.
- Food and Drug Administration (FDA). DMAA in products marketed as dietary supplements. Available online: <https://www.fda.gov/food/dietary-supplement-products-ingredients/dmaa-products-marketed-dietary-supplements>. Accessed 10 Apr 2022.
- Fortmann, S. P., Burda, B. U., Senger, C. A., Lin, J. S., & Whitlock, E. P. (2013). Vitamin and mineral supplements in the primary prevention of cardiovascular disease and cancer: An updated systematic evidence review for the U.S. Preventive Services Task Force. *Annals of Internal Medicine*, 159, 824–834.
- Gaziano, J. M., Sesso, H. D., Christen, W. G., Bubes, V., Smith, J. P., MacFadyen, J., Schwartz, M., Manson, J. E., Glynn, R. J., & Buring, J. E. (2012). Multivitamins in the prevention of cancer in men: The Physicians' Health Study II randomized controlled trial. *JAMA*, 308, 1871–1880.
- Genaro, S., & Martini, L. (2004). Vitamin A supplementation and risk of skeletal fracture. *Nutrition Reviews*, 62, 65–67.
- Giammarioli, S., Boniglia, C., Carratù, B., Ciarrocchi, M., Chiarotti, F., Mosca, M., & Sanzini, E. (2013). Use of food supplements and determinants of usage in a sample Italian adult population. *Public Health Nutrition*, 16, 1768–1781.
- Hadtstein, F., & Vrolijk, M. (2021). Vitamin B-6-induced neuropathy: Exploring the mechanisms of pyridoxine toxicity. *Advances in Nutrition*, 2, 1911–1929.
- Harsha, S. N., Suraj, M. B., Kanakavidu, S. S., & Kodali, R. (2019). Pellagra: A forgotten ailment in current clinical practice. *Medical Journal of Dr DY Patil Vidyapeeth*, 12, 78–80.
- Hemilä, H., & Chalker, E. (2013). Vitamin C for preventing and treating the common cold. *Cochrane Database of Systematic Reviews*, 2013, 1, Art. No.: CD000980.

- Holick, M. F. (2006). Resurrection of vitamin D deficiency and rickets. *The Journal of Clinical Investigation*, 116, 2062–2072.
- Huskinson, E., Maggini, S., & Ruf, M. (2007a). a). The influence of micronutrients on cognitive function and performance. *Journal of International Medical Research*, 35, 1–19.
- Huskinson, E., Maggini, S., & Ruf, M. (2007b). b). The role of vitamins and minerals in energy metabolism and well-being. *Journal of International Medical Research*, 35, 277–289.
- Khalife, R., Grieco, A., Khamisa, K., Tinmouh, A., McCudden, C., & Saidenberg, E. (2019). Scurvy, an old story in a new time: The hematologist's experience. *Blood Cells, Molecules, and Diseases*, 76, 40–44.
- Kim, J., Lee, J. S., Shin, A., Kang, M. H., Shin, D. S., Chung, H. R., & Kim, W. K. (2010). Sociodemographic and lifestyle factors are associated with the use of dietary supplements in a Korean population. *Journal of Epidemiology*, 20, 197–203.
- Knudsen, V. K., Rasmussen, L. B., Haraldsdóttir, J., Ovesen, L., Bülow, I., Knudsen, N., Jørgensen, T., Laurberg, P., & Perrild, H. (2002). Use of dietary supplements in Denmark is associated with health and former smoking. *Public Health Nutrition*, 5, 463–468.
- Kobayashi, E., Sato, Y., Umegaki, K., & Chiba, T. (2017). The prevalence of dietary supplement use among college students: A Nationwide Survey in Japan. *Nutrients*, 9, 1250.
- Li, J., Li, X., Gathirua-Mwangi, W., & Song, Y. (2020). Prevalence and trends in dietary supplement use among US adults with diabetes: The National Health and Nutrition Examination Surveys, 1999–2014. *BMJ Open Diabetes Research and Care*, 8, e000925.
- Mamtani, R., Cheema, S., MacRae, B., Alrouh, H., Lopez, T., ElHajj, M., & Mahfoud, Z. (2015). Herbal and nutritional supplement use among college students in Qatar. *Eastern Mediterranean Health Journal*, 21, 39–44.
- Marcus, D. M. (2016). Dietary supplements: What's in a name? what's in the bottle? *Drug Testing and Analysis*, 8, 410–412.
- Masumoto, S., Sato, M., Maeno, T., Ichinohe, Y., & Maeno, T. (2018). Factors associated with the use of dietary supplements and over-the-counter medications in Japanese elderly patients. *BMC Family Practice*, 20.
- Miller, M. F., Bellizzi, K. M., Sufian, M., Ams, A. H., Goldstein, M. S., & Ballard-Barbash, R. (2008). Dietary supplement use in individuals living with cancer and other chronic conditions: a population-based study. *Journal of the American Dietetic Association*, 108, 483–494.
- Moyer, A. V. (2014). Vitamin, mineral, and multivitamin supplements for the primary prevention of cardiovascular disease and cancer: U.S. preventive services task force recommendation statement. *Annals of Internal Medicine*, 160, 558–564.
- Pathak, V., Pathak, N. M., O'Neill, C. L., Guduric-Fuchs, J., & Medina, R. J. (2019). Therapies for type 1 diabetes: Current scenario and future perspectives. *Clinical Medicine Insights: Endocrinology and Diabetes*, 12, 1179551419844521.
- Radwan, H., Hasan, H. A., Ghanem, L., Alnajjar, G., Shabir, A., Alshamsi, A., & Alketbi, F. (2019). Prevalence of dietary supplement use and associated factors among college students in the United Arab Emirates. *Journal of Community Health*, 2019(44), 1135–1140.
- Samreen, S., Siddiqui, A. R., Wajid, S., Mothana, A. R., & Almarfadi, M. O. (2020). Prevalence and use of dietary supplements among pharmacy students in Saudi Arabia. *Risk Management and Healthcare Policy*, 13, 1523–1531.
- Sanad, M. H., Pryia, G., Mukhaimer, J. J., Asokan, V. G., & Belal, S. (2020). Knowledge and awareness of vitamin D deficiency among the general adult population in Bahrain: A cross-sectional study. *European Journal of Molecular & Clinical Medicine*, 7, 180–191.
- Seida, J. C., Mitri, J., Colmers, I. N., Majumdar, S. R., Davidson, M. B., Edwards, A. L., Hanley, D. A., Pittas, A. G., Tjosvold, L., & Johnson, J. A. (2014). Clinical review: Effect of vitamin D3 supplementation on improving glucose homeostasis and preventing diabetes: a systematic review and meta-analysis. *The Journal of Clinical Endocrinology & Metabolism*, 99, 3551–3560.
- Sesso, H. D., Christen, W. G., Bubes, V., Smith, J. P., MacFadyen, J., Schwartz, M., Manson, J. E., Glynn, R. J., Buring, J. E., & Gaziano, J. M. (2012). Multivitamins in the prevention of cardiovascular disease in men: The physicians' health study II randomized controlled trial. *JAMA*, 308, 1751–1760.
- Shakur, Y. A., Tarasuk, V., Corey, P., & O'Connor, D. L. (2012). A comparison of micronutrient inadequacy and risk of high micronutrient intakes among vitamin and mineral supplement users and nonusers in Canada. *The Journal of Nutrition*, 142, 534–540.
- Sirico, F., Miressi, S., Castaldo, C., Spera, R., Montagnani, S., Di Meglio, F., & Nurzynska, D. (2018). Habits and beliefs related to food supplements: Results of a survey among Italian students of different education fields and levels. *PLoS One*, 13, e0191424.
- Tangkiatkumjai, M., Boardman, H., & Walker, D. (2014). Herbal and dietary supplement use in Bangkok: a survey. *Journal of Complementary and Integrative Medicine*, 11, 203–211.
- Valavanidis, A. (2016). Dietary supplements: Beneficial to human health or just peace of mind? a critical review on the issue of benefit/ risk of dietary supplements. *Pharmakei*, 28, 69–92.
- Walrand, S. (2018). Dietary supplement intake among the elderly: Hazards and benefits. *Current Opinion in Clinical Nutrition and Metabolic Care*, 21, 465–470.
- World Health Organization. (2002). *Report of the Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases*. Geneva: World Health Organization. Available online: [https://apps.who.int/iris/bitstream/handle/10665/42665/WHO\\_TRS\\_916.pdf;jsessionid=6DDAB9216C4F2659AB15335C56E777E7?sequence=1](https://apps.who.int/iris/bitstream/handle/10665/42665/WHO_TRS_916.pdf;jsessionid=6DDAB9216C4F2659AB15335C56E777E7?sequence=1). Accessed on 16 May 2022.
- Yi, H. H., Park, A. H., Kang, H. J., Kang, H. J., Kim, W. K., Cho, G. Y., Song, R. H., & Lee, S. J. (2009). What types of dietary supplements are used in Korea? Data from the Korean national health and nutritional examination survey 2005. *Korean Journal of Family Medicine*, 30, 934–943.

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