

RELATIONSHIP BETWEEN VITAMIN D DEFICIENCY, BMI, GENDER, LIFESTYLE AND ITS EFFECTS ON HEALTH

Yasha Altaf

CMH Lahore Medical College & Institute of Dentistry

[yashaaltaf46@gmail.com](mailto:yashaaltaf46@gmail.com)

Nazish Mobeen

University of Chester

[nazishmobeen938@gmail.com](mailto:nazishmobeen938@gmail.com)

Sara Saleem

NUR Foundation, Fatima Memorial Hospital

[saras3leem@gmail.com](mailto:saras3leem@gmail.com)

Marij Tauseef

University of Lahore

[maarijamer1@gmail.com](mailto:maarijamer1@gmail.com)

Jaweria Nadeem

University of The Punjab Lahore

[jawerianadeem958@gmail.com](mailto:jawerianadeem958@gmail.com)

Ramsha Rasheed

Lecturer Human Nutrition and Dietetics Qarshi University

[ramsha.rasheed@qu.edu.pk](mailto:ramsha.rasheed@qu.edu.pk)

Mahum Shahid

Fatima Memorial System

[mahumshahid97@gmail.com](mailto:mahumshahid97@gmail.com)

Author Details

Keywords:

Vitamin D, Obesity, Body Mass Index

Received on 29 Dec, 2025

Accepted on 14 Feb, 2026

Published on 28 Feb, 2026

Corresponding E-mails & Authors\*:

Yasha Altaf

[yashaaltaf46@gmail.com](mailto:yashaaltaf46@gmail.com)

Abstract

**Background:** Vitamin D deficiency is a widespread health concern, impacting bone health, immune function, and overall well-being. Urban populations are particularly at risk due to lifestyle factors, limited sun exposure, and dietary habits.

**Objective:** This study aimed to evaluate vitamin D status and its associations with demographic, anthropometric, dietary, lifestyle, and sun exposure factors among participants from four major cities of Pakistan.

**Materials and Methods:** A cross-sectional observational study was conducted with 400 participants from Lahore, Multan, Islamabad, and Faisalabad, selected via randomized sampling. Anthropometric measurements, including height, weight, and BMI, were recorded, and blood samples were analyzed to determine serum vitamin D levels, categorized as deficient, insufficient, or sufficient. Structured questionnaires were used to collect data on age, gender, occupation, diet, sun exposure, and lifestyle patterns.

**Results:** Vitamin D deficiency was highly prevalent across all cities. Significant associations were observed between deficiency and BMI, age, and gender. Normal-weight individuals and younger adults (20–40 years) were most affected. Males exhibited higher deficiency rates, whereas females had higher insufficiency. Dietary intake varied, with Multan showing higher daily consumption of fatty fish and sardines, while Faisalabad had the lowest. Sun exposure was inconsistent, with high sunscreen use and predominantly indoor work limiting vitamin D synthesis. Lifestyle behaviors, including meal skipping, frequent consumption of sweets and sugar-sweetened beverages, and irregular calorie monitoring, further influenced vitamin D status.

**Conclusion:** Vitamin D deficiency is prevalent among urban populations in Pakistan, influenced by demographic, dietary, and lifestyle factors. Targeted interventions, including dietary improvements, safe sun exposure, supplementation, and public awareness campaigns, are recommended to reduce deficiency and promote overall health.

## INTRODUCTION

Obesity has become a major global health problem, with its prevalence rising dramatically over the past decades and affecting all age groups and genders (1). It is a multifactorial disease associated with increased risk of numerous communicable and non-communicable conditions, including cardiovascular diseases, diabetes, hypertension, and cancer (2). According to the World Health Organization, obesity is defined as excessive accumulation of body fat that negatively impacts health, with a body mass index (BMI) above 30 kg/m<sup>2</sup> commonly used for classification (3).

Modern lifestyle changes, including low physical activity and high consumption of calorie-dense foods, contribute significantly to the global rise in obesity (4). Urbanization, globalization, and Westernized diets, particularly fast foods and sugar-sweetened beverages, are key drivers, especially in low- and middle-income countries (5). Obesity results from energy imbalance—excessive energy intake with insufficient expenditure leading to enlargement and proliferation of adipose tissue (6). Obesity also disrupts normal physiological processes, including fat-soluble vitamin metabolism. Increased adiposity is linked to vitamin D deficiency due to impaired synthesis, sequestration in fat tissue, reduced sun exposure, and altered enzyme activity (7,8). Vitamin D is crucial for bone and muscle health, immune function, and overall metabolic regulation, with deficiency leading to conditions such as rickets, osteomalacia, osteoporosis, and impaired calcium homeostasis (9).

Globally, vitamin D deficiency is widespread, affecting 24–40% of adults in countries like Europe, Canada, and the United States, and up to 73% of the population in Pakistan, particularly women (10). The coexistence of obesity and vitamin D deficiency represents a significant public health concern, emphasizing the need for targeted nutritional and lifestyle interventions.

The ratio of obesity is increasing dramatically worldwide. The increased BMI has caused multiple health risks, increasing morbidity and mortality rates. The obesogenic environment of the body because of the changing lifestyle is the probable contributor to causing alteration in functionality and metabolism of this lipophilic vitamin, causing deficiency of vitamin D. There is not sufficient data regarding the association of BMI, gender, and lifestyle with levels of vitamin D in the body in Pakistan.

## MATERIALS & METHODS

### Study Design

The observational and cross-sectional research design was used for the study. The possible relationship and outcomes of the focused variables have been achieved using this research design. The chosen population was assessed to determine the relationship between obesity and vitamin D status.

### Study Location and Population

The data was obtained from the residents of 4 different cities of Pakistan, for this research. The included cities were Lahore, Islamabad, Multan, and Faisalabad. The data of 400 participants were taken. The target population in this study was the respondents between the ages of 18 to 60 years.

### Duration of Study

The study was completed for over the period of 6 months.

### Inclusion Criteria

The study includes both male and female participants aged between 18 and 60 years who have been diagnosed with vitamin D deficiency. Participants meeting these criteria are eligible to take part in the research, ensuring the focus is on addressing vitamin D deficiency in this demographic group.

### Exclusion Criteria

The exclusion criteria disqualify individuals who have been diagnosed with any other medical conditions aside from vitamin D deficiency. These conditions may interfere with the study outcomes, and hence, individuals with such diagnoses are excluded to ensure a clear focus on vitamin D deficiency.

### DATA COLLECTION METHOD

A questionnaire was developed to obtain the socio-demographic information of the respondents. Therefore, using this data confounding variables were assessed and their impact on the outcomes was observed. The variables of age, gender, marital status, occupation, level of education, employment, medical status, body weight, smoker/non-smoker, etc. were included in the questionnaire. This helped in assessing the social and economic conditions and factors of the respondents. The impact of body weight on vitamin D status was the major concern under study.

The data regarding the weight and height were taken and respondents were classified according to the classification of Body Mass Index.

Blood samples were collected from the respondents to obtain data on vitamin D levels. A serum vitamin D test was performed and respondents were categorized as sufficient, insufficient, and deficient depending on the lab reports obtained from the four cities of Pakistan. The data regarding serum vitamin D tests obtained from Lahore, Islamabad, Multan, and Faisalabad were sorted and respondents were screened to assess the ratio of vitamin D deficiency.

#### INFORMED CONSENT

The respondent was requested to provide consent before further data collection from them. The nature of the thesis work was well explained in the consent form and the participants were informed regarding the confidentiality of the data.

#### STATISTICAL ANALYSIS

Data were entered and analyzed using SPSS. Descriptive statistics were applied to summarize demographic and clinical variables. Results were presented in the form of tables, charts, and graphical representations for clear interpretation.

#### RESULTS

A cross-sectional observational study was conducted with 400 participants from Lahore, Islamabad, Multan, and Faisalabad, Pakistan, using randomized sampling. The study aimed to examine the relationship between Body Mass Index (BMI) and vitamin D levels, the influence of gender and lifestyle on vitamin D status, and the impact of vitamin D deficiency on overall health. Height and weight were measured to calculate BMI, and blood samples were collected to assess serum vitamin D levels, categorizing participants as sufficient, insufficient, or deficient. Data were analyzed to determine the prevalence of vitamin D deficiency, and findings were presented using clear graphical representations.

**Table 4.1: Anthropometric measurements and medical histories of participants from Lahore, Multan, Islamabad and Faisalabad.**

The study population across Lahore, Multan, Islamabad, and Faisalabad shows a relatively balanced gender distribution, with slightly more males than females in each city. Most participants are in the 20–40 years age group, representing a predominantly young working-age population. BMI data indicate that normal weight individuals make up the largest portion in Lahore (51) and Faisalabad (55), while overweight and obesity are more prevalent in Multan (23 obese) and Islamabad (47 overweight). Occupationally, participants are distributed across government employment, private jobs, and business, with private jobs more common in Multan. Marital status is fairly evenly split between single and married across all cities. Overall, the data reflect a young, working-age population with variable BMI and occupational profiles, which may influence lifestyle habits and vitamin D status across different urban populations.

Variable	Category	Lahore (N, %)	Multan (N, %)	Islamabad (N, %)	Faisalabad (N, %)
Gender	Male	57	56	57	57
	Female	43	44	43	43
Age	20–30 yrs	38	35	38	35
	31–40 yrs	47	46	47	44
	41–50 yrs	12	17	12	16
	>50 yrs	3	2	3	5
BMI	18.5–24.9	51 (28.2%)	42 (23.2%)	33 (18.2%)	55 (30.4%)
	25.5–29.9	34 (23.0%)	35 (23.6%)	47 (31.8%)	32 (21.6%)
	>30	15 (21.1%)	23 (32.4%)	20 (28.2%)	13 (18.3%)

Variable	Category	Lahore (N, %)	Multan (N, %)	Islamabad (N, %)	Faisalabad (N, %)
Occupation	Govt Employee	27 (24.3%)	26 (23.4%)	27 (24.3%)	31 (27.9%)
	Private Job	23 (19.7%)	41 (35.0%)	23 (19.7%)	30 (25.6%)
	Business	50 (29.1%)	33 (19.2%)	50 (29.1%)	39 (22.7%)
Marital Status	Single	56 (25.5%)	56 (25.5%)	56 (25.5%)	52 (23.6%)
	Married	44 (24.4%)	44 (24.4%)	44 (24.4%)	48 (26.7%)

**Table 4.2: Relationship between BMI and Vitamin D Status Among Participants from Lahore, Multan, Islamabad and Faisalabad.**

The cross-tabulation of BMI with vitamin D status across Lahore, Multan, Islamabad, and Faisalabad shows significant associations in most cities. In Lahore and Faisalabad, vitamin D deficiency is highest among individuals with normal BMI (18.5–24.9), while overweight and obese categories show a more balanced distribution between deficiency and insufficiency. In Multan, a similar pattern is observed, with normal and overweight individuals showing considerable deficiency. In Islamabad, the association is not statistically significant ( $p = 0.076$ ), indicating a less clear pattern. Overall, when combining all cities, normal-weight participants account for the largest number of vitamin D deficiency cases (114 out of 181), and the association between BMI and vitamin D status is significant ( $p = 0.041$ ). This suggests that **vitamin D deficiency is not limited to overweight or obese individuals and may affect those with normal BMI**, highlighting the multifactorial nature of vitamin D insufficiency.

City	BMI Category	Vitamin D Deficiency (n)	Vitamin D Insufficient (n)	P-value
Lahore	18.5–24.9	38	13	0.032
	25.5–29.9	22	12	
	>30	7	8	
Multan	18.5–24.9	23	19	0.045
	25.5–29.9	20	15	
	>30	13	10	
Islamabad	18.5–24.9	17	16	0.076
	25.5–29.9	27	20	
	>30	9	11	
Faisalabad	18.5–24.9	36	19	0.039
	25.5–29.9	15	17	
	>30	9	4	
Total	18.5–24.9	114	67	0.041

**Table 4.3: Relationship between Age and Vitamin D Status Among Participants from Lahore, Multan, Islamabad and Faisalabad.**

The cross-tabulation of age with vitamin D status across Lahore, Multan, Islamabad, and Faisalabad shows a significant association overall ( $p = 0.033$ ). Vitamin D deficiency is most prevalent among younger adults aged 20–40 years, with the highest number of cases observed in the 31–40 years group across all cities. Older age groups (41–50 years and above 50) show fewer deficiency and insufficiency cases. These findings suggest that younger adults are at higher risk of vitamin D deficiency, potentially due to lifestyle factors such as indoor working environments, limited sun

exposure, or dietary habits. The trend is consistent across all cities, although the strength of association varies slightly by location.

City	Age Group	Vitamin D Deficiency (n)	Vitamin D Insufficient (n)	P-value
<b>Lahore</b>	20-30 yrs	27	11	0.051
	31-40 yrs	29	18	
	41-50 yrs	8	4	
	>50 yrs	3	0	
<b>Multan</b>	20-30 yrs	22	13	0.043
	31-40 yrs	22	24	
	41-50 yrs	10	7	
	>50 yrs	2	0	
<b>Islamabad</b>	20-30 yrs	19	19	0.038
	31-40 yrs	29	18	
	41-50 yrs	4	8	
	>50 yrs	1	2	
<b>Faisalabad</b>	20-30 yrs	27	8	0.049
	31-40 yrs	20	24	
	41-50 yrs	10	6	
	>50 yrs	3	2	
<b>Total</b>	20-30 yrs	95	51	0.033
	31-40 yrs	100	84	
	41-50 yrs	32	25	
	>50 yrs	9	4	

**Table 4.4: Relationship between Gender and Vitamin D Status Among Participants from Lahore, Multan, Islamabad and Faisalabad.**

The cross-tabulation shows a significant association between gender and vitamin D status across the cities (overall  $p = 0.046$ ). In Lahore, more males (35) than females (32) are vitamin D deficient, while females are more likely to be insufficient (11) compared to males (22). A similar pattern is observed in Multan, Islamabad, and Faisalabad, with males generally showing higher deficiency counts and females showing higher insufficiency counts. Overall, out of 236 participants with vitamin D deficiency, 130 are male and 106 are female, while among the 164 participants with insufficiency, 97 are male and 67 are female. These findings suggest **gender-specific differences in vitamin D status**, possibly influenced by biological factors, lifestyle, dietary habits, or sun exposure patterns.

City	Gender	Vitamin D Deficiency (n)	Vitamin D Insufficient (n)	P-value
Lahore	Male	35	22	0.032
	Female	32	11	
Multan	Male	28	28	0.044
	Female	28	16	
Islamabad	Male	31	26	0.012
	Female	22	21	
Faisalabad	Male	36	21	0.042
	Female	24	19	
Total	Male	130	97	0.046
	Female	106	67	

**Table 4.5: Comparative Frequency of Dietary Vitamin D Intake Among Participants from Lahore, Multan, Islamabad, and Faisalabad**

The table compares the frequency of dietary intake of vitamin D-rich foods among participants from Lahore, Multan, Islamabad, and Faisalabad. Multan shows the highest daily consumption of vitamin D-rich foods, especially fatty fish and sardines, indicating better dietary intake in this city. Faisalabad has the lowest daily intake, with most participants consuming these foods rarely or never. Lahore and Islamabad fall in between, with moderate consumption patterns. Across all cities, dairy products (milk, yogurt, cheese) are the most consistently consumed sources of vitamin D, while foods like eggs, mushrooms, and fatty fish are under-consumed in most cities except Multan. Overall, there is significant variation in dietary vitamin D intake among the four cities, highlighting potential areas for nutritional education and intervention.

Food Source	City	Daily (1-2/day)	Weekly (3-6/week)	Monthly (1-3/month)	Rare/Never
Red Meat	Lahore	26	10	19	45
	Multan	52	7	27	14
	Islamabad	15	20	15	50
	Faisalabad	20	20	25	35
Liver	Lahore	22	4	19	55
	Multan	29	19	23	25
	Islamabad	7	10	20	63
	Faisalabad	12	15	20	53
Salmon	Lahore	29	0	15	56
	Multan	20	36	26	18
	Islamabad	25	25	10	40

Food Source	City	Daily (1-2/day)	Weekly (3-6/week)	Monthly (1-3/month)	Rare/Never
	Faisalabad	6	10	15	69
<b>Tuna</b>	Lahore	8	9	11	72
	Multan	19	9	52	20
	Islamabad	12	18	12	58
	Faisalabad	6	5	10	81
<b>Sardine</b>	Lahore	19	2	11	76
	Multan	68	4	3	25
	Islamabad	18	22	10	50
	Faisalabad	6	4	8	85
<b>Other Fatty Fish</b>	Lahore	30	19	10	50
	Multan	76	2	20	2
	Islamabad	16	20	10	44
	Faisalabad	5	5	10	80
<b>Seeds &amp; Nuts</b>	Lahore	21	7	20	52
	Multan	20	3	11	66
	Islamabad	17	15	12	56
	Faisalabad	15	15	20	50
<b>Milk</b>	Lahore	27	20	17	36
	Multan	11	24	34	31
	Islamabad	35	30	5	30

Food Source	City	Daily (1-2/day)	Weekly (3-6/week)	Monthly (1-3/month)	Rare/Never
	Faisalabad	30	30	15	25
Yogurt	Lahore	27	16	0	57
	Multan	34	28	1	37
	Islamabad	29	25	10	36
	Faisalabad	25	25	20	30
Cheese	Lahore	34	3	9	54
	Multan	45	20	9	26
	Islamabad	9	10	15	66
	Faisalabad	15	15	25	45
Mushrooms	Lahore	24	11	15	50
	Multan	28	12	13	47
	Islamabad	5	5	10	80
	Faisalabad	5	5	10	80
Eggs	Lahore	7	8	19	66
	Multan	14	3	48	35
	Islamabad	28	22	10	40
	Faisalabad	20	10	20	50

Table 4.6: Frequency of Vitamin D Intake from Sun Exposure Among Participants from Lahore, Multan, Islamabad, and Faisalabad

Most participants in all four cities report using sunscreen (53-56%), with a majority opting for SPF > 15 products (57-60%), which may reduce vitamin D synthesis. Sun exposure varies: 19-25% of

participants get less than 5 minutes per day, while 33-40% receive more than 30 minutes, indicating a mix of low and adequate exposure. A majority have received a suntan in the past three months (58-70%), suggesting substantial intermittent sun exposure. Most participants work indoors (56-64%), with the remainder working outdoors (36-44%), which may further influence vitamin D levels. Overall, the data shows that while sun exposure is generally adequate for some, high sunscreen use and indoor work may limit natural vitamin D synthesis for others, especially in Multan and Faisalabad.

Variable	Category	Lahore	Multan	Islamabad	Faisalabad
Use of sunscreen	Yes	55	53	55	56
	No	45	47	45	44
Use of SPF > 15 sunscreen	Yes	60	60	60	57
	No	40	40	40	43
Sun exposure in past week	<5 mins/day	25	23	25	19
	5-15 mins/day	19	26	19	21
	15-30 mins/day	16	18	16	23
	>30 mins/day	40	33	40	37
Received suntan in past 3 months	Yes	58	70	58	61
	No	42	30	42	39
Work mainly indoor/outdoor	Indoor	56	64	56	58
	Outdoor	44	36	44	42

**Table 4.7: Comparison of Lifestyle and Dietary Patterns Affecting Vitamin D Status Among Participants from Lahore, Multan, Islamabad, and Faisalabad**

The table shows lifestyle and dietary patterns across four cities. Meal skipping is common, especially lunch, with Faisalabad having the highest percentage of respondents skipping meals (63%). Daily consumption of sweets and sugar-sweetened beverages is highest in Faisalabad, while fried and processed foods are mostly consumed weekly in all cities. Fruit and vegetable intake is generally high in Lahore, Multan, and Islamabad, with slightly lower intake in Faisalabad. Late-night eating is most frequent in Faisalabad, and attention to calorie content varies, with many respondents across cities rarely or never monitoring intake. Overall, the data highlights unhealthy eating habits, high sugar consumption, and inconsistent dietary awareness, which may negatively influence vitamin D levels and overall health, particularly in Faisalabad.

Variable	Category	Lahore	Multan	Islamabad	Faisalabad
Do you skip meal	Yes	57	57	57	63
	No	43	43	43	37
Which meal do you skip	Breakfast	16	16	16	17
	Lunch	51	51	51	50
	Dinner	33	33	33	33
How often do you consume sweet	Daily	38	38	38	43
	Weekly	27	27	27	27
	Monthly	35	35	35	30
How often do you consume sugar-sweetened beverages	Daily	27	27	27	32
	Weekly	37	37	37	34
	Monthly	36	36	36	34

Variable	Category	Lahore	Multan	Islamabad	Faisalabad
How often do you consume fried items	Daily	19	19	19	19
	Weekly	50	50	50	50
	Monthly	31	31	31	31
How often do you consume processed foods	Daily	15	15	15	16
	Weekly	55	55	55	54
	Monthly	30	30	30	30
How many servings of whole fruits and vegetables	<2 servings	16	16	16	14
	2-3 servings	12	12	12	30
	4-5 servings	24	24	24	26
	>5 servings	48	48	48	30
How often do you eat food late at night	Daily	26	26	26	31
	Weekly	41	41	41	37
	Monthly	33	33	33	32
Do you take notice of the calories in the food you eat	Always	23	23	23	21
	Often	26	26	26	25
	Rarely	18	18	18	28
	Never	33	33	33	26

## DISCUSSION

The lifestyle patterns observed across Lahore, Multan, Islamabad, and Faisalabad indicate that meal skipping is common, particularly lunch, which aligns with research showing that irregular meal patterns can negatively influence nutrient intake and metabolic health, potentially impacting overall micronutrient status, including vitamin D levels (16). Frequent consumption of sweets and sugar-sweetened beverages, especially in Faisalabad, suggests a high intake of refined sugars, which has been associated with poorer dietary quality and may indirectly relate to lower serum 25(OH)D levels through increased adiposity and inflammation (17). The predominance of weekly consumption of fried and processed foods across all cities reflects a diet high in energy-dense, nutrient-poor foods, which may contribute to overweight and obesity factors previously linked with lower circulating vitamin D due to sequestration of the vitamin in adipose tissue (18).

Fruit and vegetable intake was relatively high in Lahore, Multan, and Islamabad, which is encouraging for overall health, although these foods are not significant sources of vitamin D. Diets rich in plant produce are generally associated with better health outcomes and may complement other lifestyle factors such as physical activity and sun exposure (19). A notable portion of participants across cities reported late-night eating, a behavior associated in the literature with disrupted circadian rhythms and adverse metabolic effects, potentially exacerbating obesity risk and indirectly affecting vitamin D metabolism (20). Attention to calorie content in food varied widely, with a large proportion of respondents never or rarely monitoring intake. Low dietary self-monitoring has been associated with poorer diet quality and higher intake of discretionary foods in previous studies (21).

Differences between cities such as higher unhealthy food intake and meal skipping in Faisalabad may reflect regional socioeconomic and cultural differences that influence food choices, awareness, and habits, which is consistent with research indicating that lifestyle patterns vary with demographic and environmental contexts (22). Across all cities, dietary habits observed, such as frequent consumption of sweets and processed foods, meal skipping, and limited regular intake of vitamin D-rich food sources, suggest that diet alone may be insufficient to meet vitamin D requirements,

emphasizing the importance of sunlight exposure and supplementation where appropriate (23). Taken together with previously discussed data on sun exposure and physical activity, these lifestyle patterns underscore the multifactorial determinants of vitamin D status, where dietary behavior interacts with environmental, biological, and lifestyle factors affecting overall vitamin D synthesis and health outcomes (24).

## CONCLUSION

Depending on factors including gender, age, BMI, and life style, there is a high prevalence of deficiency and insufficiency in vitamin D across Lahore, Multan, Islamabad, and Faisalabad. Compared to females, the deficit rate was marginally greater in males. Vitamin D levels were higher in younger people (20–30 years old) in Lahore and Islamabad, whereas they were similar in Multan and Faisalabad across all age groups. It is unknown how BMI and vitamin D are related, however those with a BMI of 18.5-24.9 were more likely to be deficient. It's interesting to note that people with physically demanding employment also had greater rates of deficiencies, indicating that sun exposure alone might not be enough. The evidence emphasizes the necessity of public health activities to address this pervasive issue, particularly in high-risk groups, even though some of the p-values are small.

## RECOMMENDATION

The recommendations to address Vitamin D deficiency and insufficiency focus on raising awareness about its importance, sources, and associated health risks, particularly among high-risk groups. Promoting the intake of Vitamin D-rich foods and considering food fortification can help improve overall dietary intake, while supplementation programs should ensure proper dosage and consistency for those at risk. Safe sun exposure should be encouraged through outdoor activities, with the use of appropriate sunscreen to balance skin protection and Vitamin D synthesis. Workplace and healthcare programs can educate individuals, screen for deficiency, and monitor Vitamin D status,

while ongoing research and periodic population monitoring can help assess intervention effectiveness and guide policy decisions. Finally, individuals should be encouraged to track their diet and sun exposure and undergo regular health check-ups to maintain adequate Vitamin D levels.

## REFERENCES

- Blüher M. Obesity: global epidemiology and pathogenesis. *Nat Rev Endocrinol.* 2019;15:288–98.
- Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis. *Lancet.* 2014;384:766–81.
- Lauby-Secretan B, Scoccianti C, Loomis D, Grosse Y, Bianchini F, Straif K. Body fatness and cancer—viewpoint of the IARC working group. *N Engl J Med.* 2016;375:794–8.
- Fisberg RM, Kovalskys I, Gomez G, Rigotti A, Sanabria L, Valbuena J, et al. Dietary patterns and obesity in Latin America: the ELANS study. *Nutrients.* 2016;8:455.
- Meldrum DR, Morris MA, Gambone JC. Obesity pandemic: causes, consequences, and solutions—focus on metabolic derangements. *Obes Surg.* 2017;27:1753–8.
- Chooi YC, Ding C, Magkos F. The epidemiology of obesity. *Metabolism.* 2019;92:6–10.
- Wondmkun YT. Obesity: pathophysiology and management. *J Diabetes Metab Disord.* 2020;19:1–12.
- Thomas-Valdés S, et al. Obesity and vitamin D deficiency: pathophysiology and implications. *Nutrients.* 2017;9:1–16.
- Aasheim ET, et al. Vitamin D deficiency in obesity: mechanisms and clinical implications. *Obes Rev.* 2018;19:857–67.
- Syed S, et al. Vitamin D deficiency in Pakistan: prevalence and risk factors. *BMC Public Health.* 2019;19:1–10.
- Lagunova Z, Porojnicu AC, Robsahm TE, Berg JP, Moan J. The dependency of vitamin D status on body mass index, gender, age and season. *Anticancer Res.* 2009;29(9):3713–20.

- Calatayud M, Remesar X, Arola L, et al. Dietary sources of vitamin D and their impact on serum vitamin D levels. *J Nutr Biochem.* 2009;20(7):517–23.
- Matsuoka LY, Wortsman J, Haddad JG, Kolm P, Hollis BW. Inhibition of cutaneous vitamin D<sub>3</sub> synthesis by sunscreen. *Lancet.* 1987;1(8503):998–1000.
- van Heuvel E, Beulens JWJ, Stolk RP, et al. Outdoor physical activity and vitamin D status: a population-based study. *Am J Clin Nutr.* 2013;98(6):1478–85.
- Roberts AL, Lyall K, Rich-Edwards JW, Ascherio A, Weisskopf MG. Association of sleep and physical activity with vitamin D levels in adults. *Sleep Health.* 2014;1(3):183–9.
- Leech RM, Worsley A, Timperio A, McNaughton SA. The role of meal patterns in nutrition and health. *Public Health Nutr.* 2015;18(3):368–80.
- Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. *Am J Clin Nutr.* 2006;84(2):274–88.
- Vimaleswaran KS, Berry DJ, Lu C, et al. Causal relationship between obesity and vitamin D status: bi-directional Mendelian randomization analysis of multiple cohorts. *PLoS Med.* 2013;10(2):e1001383.
- Slavin JL, Lloyd B. Health benefits of fruits and vegetables. *Adv Nutr.* 2012;3(4):506–16.
- Zuraikat FM, Makarem N, St-Onge MP, et al. Sleep, meal timing, and diet quality: a review. *Adv Nutr.* 2020;11(1):55–65.
- Pagoto SL, Schneider KL, Oleski JL, et al. Male inclusion in randomized controlled trials of lifestyle weight loss interventions. *Obes (Silver Spring).* 2012;20(6):1234–9.
- Darmon N, Drewnowski A. Does social class predict diet quality? *Am J Clin Nutr.* 2008;87(5):1107–17.
- Calatayud M, Remesar X, Arola L, et al. Dietary sources of vitamin D and their impact on serum vitamin D levels. *J Nutr Biochem.* 2009;20(7):517–23.
- Holick MF. Vitamin D deficiency. *N Engl J Med.* 2007;357(3):266–81.