Observational study
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Vitamin D status of inmates: the experience of penitentiaries prisons in the province of Salerno in Southern Italy

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Abstract

Introduction. Prisoners are at risk of developing vitamin D deficiency due to their lacking exposure to sunlight. So far, there are no published studies evaluating blood levels of vitamin D in relation to the health status of inmates and the quality of the Italian prison system

Aim. To investigate vitamin D status and its determinants in a cohort of prisoners.

Subject and Methods. One hundred and seventy-two (172) prison inmates (males, n=159, age 47± 11.3 years; females, n=13, age 43.91±12.18 years) of three penitentiaries in the province of Salerno. Vitamin D deficiency, insufficiency and sufficiency were respectively defined as a 25(OH)D level <20 ng/mL; from 20 to 30 ng/mL, >30 ng/mL.

Results. In our group, Vitamin D deficiency occurs in 77.32% of the prisoners with 32.55% of the cases having severe insufficiency. Prisoners with higher BMI show lower circulating vitamin D levels ($p<0.001$). No significant relationship was found with the du-ration of detention (Pearson R: 0.01).

Conclusion. In this cohort of inmates the vitamin D status is determined by BMI, but not by the duration of the detention. ***Clin Ter 2022; 173 (6):551-556 doi: 10.7417/CT.2022.2481***

Key words: *vitamin D, prisons, right to health, inmates blood deficiency, prisons, prisoners, Italy*

Introduction

Prisoners have poor nutritional status and poor health compared to the general population (1). This disparity has been attributed to various behavioral and socioeconomic factors that raise the risk of cardiovascular disease and of some cancers (1). Studies of USA and UK prison inmates showed poor intake of vitamin D (2,3), but in a recent study, vitamin D status was determined by skin pigmentation, seasons and the security level of incarceration (4).

Vitamin D is a lipophilic hormone, playing a key role in bone metabolism and calcium homeostasis, mainly acting by binding the vitamin D receptor (VDR), which distribution involves almost all human tissues and cells (5).

Humans obtain vitamin D from either sunlight exposure or dietary foods and supplements. Vitamin D3 is synthesized endogenously in the skin and found naturally in oily fish and cod liver oil. Cutaneous synthesis of vitamin D3 requires the exposure of UVB at wavelength of 290 e 315 nm. Once vitamin D enters the circulation, it binds with a transport protein and is then stored in the adipose tissue. It is metabolized by 25-hydroxylase (CYP2R1) in the liver to 25-hydroxyvitamin D (25(OH)D), which is then converted by the 25-hydroxyvitamin D-1a-hydroxylase (CYP27B1) in the kidneys to the active form, 1,25-dihydroxyvitamin D (1,25(OH)2D). 1,25(OH)2D binds to intracellular nuclear vitamin D receptor (VDR) to exert its physiologic functions (6, 7).

Vitamin D displays its calcemic and phosphatemic effects by altering the expressions of several genes in the small intestine, kidneys, and bone. Activation of VDR by 1,25(OH)2D promotes intestinal calcium and phosphate absorption, renal tubular calcium reabsorption, and calcium mobilization from the bone (8). Vitamin D has a multitude of non-calcemic actions. This is due in part to the presence of the VDR in most tissues and cells including the skin, skeletal muscle, adipose tissue, endocrine pancreas, immune cells, blood vessels, brain, breast, many cancer cells, and placenta. There is evidence that activation of the VDR by 1,25(OH)2D results in a multitude of biologic activations in these tissues through both genomic and non-genomic pathways (9). Indeed, recent data have demonstrated modulation of extra-skeletal effects such as the immune system, cardio-vascular diseases, insulin resistance, type 2 diabetes and cancer, conditions commonly linked with obesity (10). The prison population is known to suffer from many chronic diseases such as diabetes, autoimmune diseases, cardiovascular diseases, as well as bone diseases (2, 11).

This is the first published research into vitamin D levels in an Italian prison population. Our aim was to determine the

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baseline vitamin D profiles of prison inmates and to investigate the determinants of vitamin D status in this population.

Material and Methods

Ethical Approval and Informed Consent

The data processing complied with the general authorization for scientific research purposes granted by the Italian Data Protection Authority (1 March 2012 published in Italy's Official Journal n. 72 dated 26 March 2012) since the data do not entail any significant personalized impact on the data subjects. Approval by an institutional and/or licensing committee was not required since experimental protocols were not applied in the study.

Protocols and screening were conducted as suggested by the World Health Organization and in conformity with the ethical guidelines of the 1975 Declaration of Helsinki.

Subjects

We studied a cohort of prison population of three penitentiaries in the province of Salerno. The health aspects of the prisoners are under the control of the Department of Territorial Activities Department, U.O.S.D. Protection for Adults and Minors of the ASL Salerno Criminal Area.

We included in our study one hundred and seventy-two (172) prison inmates (159 males and 13 females) who had obtained a serum 25(OH)D as part of a routine biochemical laboratory testing and not due to any specific investigation for pathologies associated with vitamin D metabolism. The blood samples were performed from October 2020 to September 2021. Inmates signed an informed consent to perform routine laboratory testing. Subjects were excluded if they had received pharmacological vitamin D or calcium supplementation prior to the date of 25(OH)D measurement. No prison inmate was excluded based on the above criteria. No prison inmates had bone, parathyroid gland, kidney and liver diseases. Because vitamin status could vary with sunlight exposure and season, we classified each inmate's date of vitamin D draw according to the seasons as follows: fall (September 22-December 21), winter (December 22-March 21), spring (March 22-June 21) and summer (June 22-September 21). Thirty-one (31) inmates performed blood sample on fall, eighty-seven (87) inmates performed blood sample on winter, forty-seven (47) inmates performed blood sample on springs and seven (7) in mates performed blood sample on summer.

One hundred and seventy-two (172) inmates (males=159, age= 47±11.3 years, females=13, age: 43.91±12.18 years) were analyzed for this study.

With respect to sun exposure, inmates were allowed an average daily sun exposure of about 3 hours/day (from 08:00/09:00 am to 11:00-12:00 am).

Methods

Vitamin D intake

All subjects in the three detention centers can choose whether to provide for their own food or to receive the diets that were approved by the Ministry of Justice that provides approximately 300 UI/day of vitamin D.

Anthropometry

Height and weight were measured in light clothing, with no shoes, using an upright scale. Body mass index (BMI) was calculated using the formula weight/height2, (Kg/m)2. Subjects were categorized into normal weight, overweight and obese groups, based on BMI criteria as BMI< 25 Kg/m2, 25-29.9, and ≥30 Kg/m2.

Assay

Serum levels of 25(OH)D were analyzed by chemiluminescence (Architect 25-OH vitamin D microparticle immunoassay, Abbot Diagnostics, Lake Forest, IL, USA) which has a 100% cross-reactivity with both metabolites of 25(OH)D namely, 25(OH)D2 and 25(OH)D3 and thus measures total serum 25(OH)D content. Its functional sensitivity is 2.2 ng/mL, and its intra- and inter-assay coefficients of variation are 4.3% and 7.9% respectively. The reportable range of assay is 3.4-156 ng/mL The analyses were performed in an approved laboratory with internal and external quality control using the reagents provided by the manufacturer and following the manufacturer's instructions. Data were compared with accepted clinical cut-off values.

Vitamin D Status

Vitamin D sufficiency was defined as 25(OH)D concentration ≥ 30 ng/ml; vitamin D insufficiency as a 25OH(D) of 20-30 ng/mL, and vitamin D deficiency as a 25(OH)D level < 20 ng/mL according to the Endocrine Society criteria(8).

Results

Proportion of subjects with Vitamin D deficiency, insufficiency and sufficiency.

In our cohort, the overall proportion of inmates with vitamin D deficiency is 77.32% (133/172), and in particular 32.5% (56/172) presents 25(OH)D levels < 10 ng/mL, vitamin D insufficiency is 23.8% (41/172) and vitamin D sufficiency is only 4.6% (8/172). In male inmates the average 25OHD levels is 15 ±9 ng/mL. The proportion of vitamin D deficiency is 79.3% (126/159), vitamin D insufficiency is 22.6% (36/159) and only the 4.4% (7/159) presents 25(OH)D levels in the normal range. In female, the average 25(OH)D level is 21 ± 17 ng/mL. The female population is not numerically adequately represented, however 7/13 (53%) inmates have vitamin D insufficiency. In white inmates, the mean serum concentration of 25OHD is 14 ± 16 ng/mL and the proportion of vitamin D deficiency is 70.8% (114/161). In black inmates, the mean serum concentration of 25(OH)D is 8 ± 10 ng/mL. The proportion of vitamin D insufficiency is 81.8% (9/11). We did not have adequate power to determine a difference between white (161) and blacks (11) inmates (Table 1).

Table 1. Characteristics of inmates stratified by sex

Parameters (± SD)	Male = 159 (92.44/)	Female = 13 (7,56%)
Age	47 ± 11	44 ± 12
Hieght (m)	1.74 ± 0.07	1.60 ± 0.07
Wheight (kg)	66± 18	67 ± 14.5
Body mass Index (kg/m)²	29 ± 6	26 ± 5
<25	42 (26.41)	7 (53.84)
25-29.9	62 (39.00)	3 (23.07)
>30	55 (34.59)	3 (23.07)
Duration of the detention (months)	18± 19	15 ± 19
Ethnicity		
White	148 (93.08)	13 (100)
Black	11 (6.92)	0 (0.00)
25(OH)D levels (ng/ml)	15 ± 9	21± 17
<20 ng/ml	126 (79.24)	7 (53.84)
20 - 30 ng/ml	26 (16.35)	5 (38.46)
30 - 100 ng/ml	7 (4.41)	1 (7.70)

The determinants of Vitamin D status

BMI

The mean BMI of the inmates is 26.1 Kg/m2 (Min 18.04, Max 47.32, Median 27.66). Obesity occurs in 33.7% of inmates (58/172) and overweight occurrs in 37.8% (65/172) of inmates. There is a significant correlation between BMI and 25(OH)D levels in all inmates ($p<0.001$) (Fig. 1).

Duration of Detention

The mean time between sample and the beginning of detention is 18±19 (IQ1 2; IQ3 28) months. There is no significant relationship between the duration of incarceration and 25(OHD) levels (P: 0.2, 95% confidence intervals -1.0 to 5.4, Pearson R: 0.01, r^2:0.010) (Fig. 2).

Discussion

In our preliminary study for the first time the prevalence of vitamin deficiency in an Italian prison population is described. In our cohort overall 77.3% of inmates present vitamin D deficiency and in particular 32.5% severe vitamin D deficiency. This prevalence is significantly higher than that found in the general adult population where the prevalence, depending on the cut-off used (8), (12), varies between 25% to 42%(13). Vitamin D deficiency is a worldwide public health problem affecting all age groups. It is estimated that 1 billion people worldwide have vitamin D deficiency (25(OH) D <20 ng/mL) or insufficiency (25(OH)D <30 ng/mL) (14). A severe deficit is found in 7% of the world population with considerable differences observed among different countries and populations (15). Nevertheless, severe vitamin D deficiency occurs in high risk population such as those who lack effective exposure to sunlight (16). In our study population, the severe deficit is found in 32.5% of the cases, classifying the prisoners as subjects at risk of severe vitamin D deficit due to their unfeasibility to adequate sunlight exposure.

Severe vitamin D deficiency is associated with increased mortality (17), but this condition does not interfere with the execution of the sentence. The Italian legislation provides that the execution of the sentence of imprisonment is postponed due to pregnancy, maternity of a child under the age of 1, people suffering from full-blown AIDS (18, 19) or other serious pathologies, not compatible with the incarceration, which does not respond to due therapy (20, 21). Vitamin D deficiency should be taken into consideration when assessing compatibility with the prison. The severe deficit alone does not make the subject incompatible, as the pathology responds in an excellent way to therapy.

The vitamin D synthesis in the skin is the most important source of vitamin D and depends on phenotypes (22)

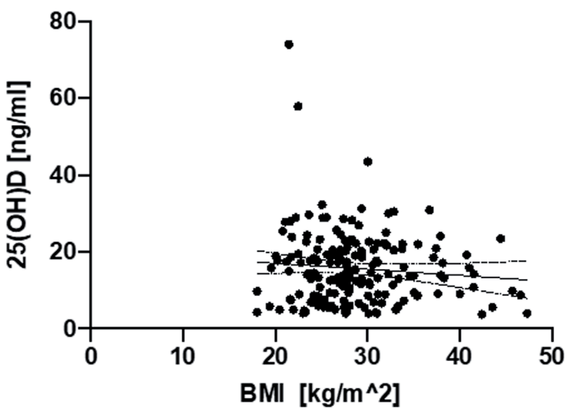

Fig. 1. The relationship between 25(OH)D concentration and the BMI (pearson r: -0.63 95% CI -0.2419 to 0.055 R2 0.31)

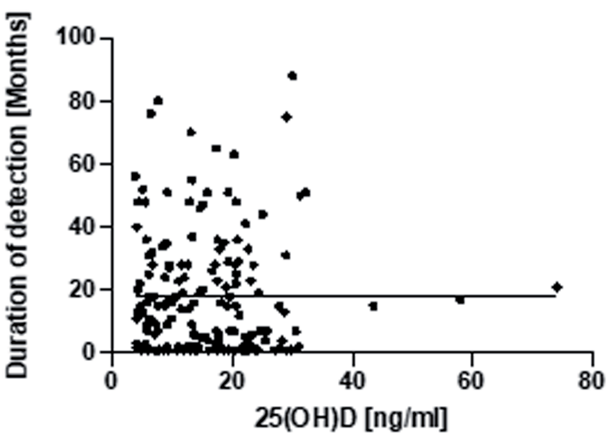

Fig. 2. The relationship between 25(OH)D concentration and the duration of the detention.

and on the intensity of the ultraviolet irradiation which is dependent on the season, the latitude and air pollution (16). Italian epidemiologic studies reported that vitamin D levels differed by near 40% among subjects with either a low or an average sun exposure, suggesting a 60-90% contribution of the sun exposure to vitamin D synthesis (23). Inmates have a guaranteed, but limited time of sun exposure (about 3 hours), at times that do not always ensure appropriate sun exposure for vitamin D synthesis (24). Therefore, the prisoners are to be included in the population at risk of severe vitamin D deficit.

In young adults, a summer sun exposure of about 25% of body surface (face and arms) for 15 minutes twice or three times a week is equivalent to an oral dose of 100 UI of vitamin D (25). Hence, sun exposure in specific time slots would allow to contain insulation damage of prisoners and ensure adequate endogenous vitamin D skin production (26).

In the three penitentiaries, inmates can choose whether to autonomously provide for their own diet or receive food administered by the prison following the ministerial guidelines (27).

Diet can be an important determinant of vitamin D status and is influenced by the cultural nutritional practice and national policy (28). However, dietary intake does not provide more than 20% of the daily vitamin D requirements with the major sources being dairy and cereals products (but only if fortified), eggs yolks and oil fish and meat. Mushrooms have very little vitamin D2 unless they are UV irradiated (29). In the USA vitamin D is mainly ingested through fortified foods (30). In Italy, in general population, the dietary contribution to the desirable plasma levels of vitamin D is considerably lower than in the USA, due to the composition of the diet (with less animal fats) and to a lack of appropriate fortification and supplementation foods. Diet provides approximately 300 IU/day also in Winter, when the sun exposure is virtually absent (23, 31, 32). Therefore, prison inmates are at risk of developing severe vitamin D deficiency due to the association of two risk factors, namely isolation and insufficient dietary intake of vitamin D.

In our population, vitamin D levels are linearly correlated to the BMI. In particular, more severe vitamin D deficiency is associated with higher BMI values.

Vitamin D deficiency is a well-recognized common feature of people with obesity, suggesting that the adipose tissue might play a role in the low vitamin D levels (33, 34). The prevalence of vitamin D deficiency is 35% and 24% higher in obese and overweight subjects, respectively (33) and it has been observed that for every increase in BMI there is an associated reduction of approximately 1% in vitamin D levels (35). The causal relationship between obesity and low levels of circulating vitamin D has been partially clarified in a bi-directional Mendelian randomization analysis in which higher BMI leaded lower vitamin D levels (36). It has been proposed that vitamin D, being fatsoluble, could be isolated in body fat depots, leading to lower bioavailability in the obese state (37, 38). Alternatively, it has been hypothesized an alteration of the metabolism of vitamin D within the adipocytes (39, 40). Really, it cannot be excluded that a bidirectional causal relationship exists where a low vitamin D status represents a risk factor of adiposity excess. Indeed, it has been hypothesized that lower vitamin D values in the obese may be independent predictors of obesity rather than secondary to this condition (41). Thus, hypovitaminosis D could contribute to adipose tissue accrual with a consequent negative impact on metabolic homeostasis leading to many comorbidities, including insulin resistance and type 2 diabetes mellitus (42) and in-creasing the risk of cardiovascular disease and all-cause mortality (42) at Mendelian randomization analyses (43). Finally, a recent study aimed at evaluating the association between BMI and vitamin D levels in COVID patients, showing that overweight subjects with hypovitaminosis D suffered from more severe clinical forms, with worse inflammatory parameters and worse outcome than patients with one or neither of the two conditions (44, 45), (46). Indeed, in the general population has been described an association between vitamin D deficiency and higher risk of COVID infection as well as more severe outcome (high probability of hospitalization and mortality(47, 48)). Vitamin D supplementation seems to prevent COVID-infection (49), regardless vitamin D status (50), and to reduce mortality in hospitalized COVID-patient (51, 49, 52, 53).

This emphasizes the role of vitamin D in protecting health of the prison population, which is more exposed to cardiovascular diseases and infections and in general with a worse health status than general population.

In our study there is no statistically significant correlation between vitamin D levels and the duration of the detention. This is partially in agreement with a recent study in which inmates, stratified by age, sex and BMI, showed acorrelation between vitamin D levels and duration of the detention (4). However, this correlation was not confirmed when the analysis was limited to inmates at the highest level of safety, and which were allowed only 1 hour a day of recreational activities, under strict surveillance. Furthermore, inmates at the highest security level had significantly lower levels of vitamin D than those at medium and lowest security levels. Therefore, it was identified a subgroup of prison inmates at greater risk of developing severe vitamin D deficiency in relation to level of isolation. Although there is no correlation with detention time, the prison population showed a significantly higher vitamin D deficiency than that found in the general adult population.

This study has some limitations. First, we did not study the entire prison population, but only those with laboratory values of vitamin D that met with the inclusion criteria. Furthermore, it was not possible to perform an analysis based on uniform patterns of nutritional intake. We also did not have adequate power to detect a significant difference in vitamin D levels between white e black inmates and between male and female inmates, because of the very few black inmates and female inmates. Finally, it was not possible to verify the effect of season on levels of vitamin D because the representative data on vitamin D levels were not available for all seasons of the years.

Conclusion

This study shows the high prevalence of vitamin D deficiency in a sample of prison population of three penitentiaries in the province of Salerno. The main determinant of vitamin D status in prisoners is high the BMI. By now it is clear that vitamin D levels are not only predictors of bone health, but also independent predictors of other diseases, in particular cardiovascular and infectious diseases, that prisoners show more frequently, probably due to the environmental conditions in which they live in. The maintenance of normal circulating levels of vitamin D is needed to ensure optimal muscular and skeletal health and to oppose obesity and associated comorbidities, as well as the risk of infections, including COVID-19. Therefore, it would be recommendable to implement screening of the vitamin D status on all prisoners and to perform a closely monitoring of overweight and obese subjects, who are at the greatest risk to develop a severe deficiency. Furthermore, it would be advisable to consider the introduction of fortified foods with vitamin D to guarantee an adequate dietary intake, in accordance with the guidelines for the high-risk categories, and supplementation protocols (1000-2000 to 4000 UI/day) to prevent deficiency conditions. Although it is not necessary to postpone the incarceration, vitamin D deficit remains a major problem for the prison population. New models of prison and extra-prison detention could include other re-education measures that take into account this risk.

In conclusion, in penitentiaries it is critical to implement a structured vitamin D status assessment program with specific guidelines regarding nutrition. This aims to ensure musculoskeletal and cardiovascular health, prevent associated complications, such as falls, fractures, hypertension and diabetes mellitus, and help reduce the unnecessary healthcare expenditures on these preventable comorbidities.

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