2018

Vitamin D deficiency and segregation status in prisoners

Zelda Doyle

The University of Notre Dame Australia, zelda.doyle@nd.edu.au

John Dearin

The University of Notre Dame Australia, john.dearin@nd.edu.au

Joe McGirr

This article was originally published as:

Doyle, Z., Dearin, J., & McGirr, J. (2018). Vitamin D deficiency and segregation status in prisoners. *International Journal of Prisoner Health, 14* (1), 16-25.

Original article available here:

10.1108/IJPH-11-2016-0067

Article Type

Original Research

Title

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Structured Abstract

Purpose:

The purpose of this paper was to investigate if any exposure to segregation minimal association (SMAP) in a single male prison population had any association with an increased risk of Vitamin D deficiency.

Design and Methodology:

This study utilised a retrospective case study with all inmates who had a 25-hyrdoxy-Vitamin D test taken during the study period deemed eligible. Hand searching of the medical records by an independent party identified eligible participants whose data was recorded for analysis.

Findings:

One hundred and twenty-four prisoners were deemed eligible for inclusion. Sixty-seven were Vitamin D sufficient and fifty-seven were vitamin D deficient by Australian standards. Time in SMAP was shown not to be significant, however, smoking (OR 2.93 (95% CI 1.27 – 6.81,p=0.012) and having Asian ethnicity (OR 4.16, 95% CI 1.56 – 11.10, p=0.004) independently significantly increased the risk of vitamin D deficiency.

Research Limitations and Implications:

This research is limited by its study design, small sample size and single location.

Originality/Value:

This paper presents the first published research into Vitamin D levels in a prison population in Australia, and provides a basis for a larger prospective cohort study.

Keywords

Vitamin D, deficiency, prison population, Australia, segregation, Public health

Introduction

Vitamin D is utilised predominately in the body in bone remineralisation and metabolism. It is synthesized in skin from 7-dehydrocholesterol by exposure to direct sunlight (ultraviolet B radiation) and obtained in the diet chiefly through fish liver oils and salt water fish (Johnson, 2007) . Adults who are deficient in vitamin D can suffer from osteomalacia and/or osteopenia (Kumar & Clark, 2009). Low levels of vitamin D have also been linked to an increased risk of multiple sclerosis, diabetes, heart disease, mental illness and various autoimmune diseases, (Department of Health State Government of Victoria, 2012; Holick, 2004, 2006) and there is evidence that deficiency may play a role in multiple organ systems (Clifton-Bligh, 2012; Office of Dietary Supplements, 2011). Physiological mechanisms limit the formation and metabolism of Vitamin D cutaneously, and while it is possible to ingest

large doses of Vitamin D through supplementation vitamin D toxicity is rare (Haines & Park, 2012).

Exposure to sunlight, cloud cover and other environmental factors may influence Vitamin D serum levels and explain the wide variation seen between individuals on which the reference levels in Australia are based (Commonwealth of Australia, 2006; Glendenning, 2015). Cutaneous exposure for Vitamin D is also complicated by skin colour variations: highly melanised skin has been shown to be less effective in Vitamin D uptake (Clemens, Henderson, Adams, & Holick, 1982; Norman, 1998; Yuen & Jablonski, 2010). It is often assumed that the majority of Australians will obtain most, if not all, of their vitamin D through cutaneous exposure to sunlight (Holick, 2001), but current literature suggests that this is not necessarily the case (Boyages & Bilinski, 2012; Erbas, Ebeling, Couch, & Wark, 2008; Fuller & Casparian, 2001; Holick, 1995, 2006; Nowson & Margerison, 2002; Paxton et al., 2013; Pludowski et al., 2013; Teale & Cunningham, 2010; Vieth, 1999). There may be clusters of people who do not have sufficient exposure to sunlight for adequate Vitamin D production due to a variety of factors, including religious beliefs, geography, institutionalisation or the fact they are bed bound (Boyages & Bilinski, 2012; Erbas et al., 2008). Current guidelines suggest an average intake of 5 – 15 µg/day of Vitamin D for adults increasing with increasing age is sufficient to maintain a Vitamin D (25(OH) D) serum level of at least 27.5 nmol/L if there is minimal or no exposure to sunlight (Commonwealth of Australia, 2006). It is acknowledged by Nowson et al. (2012) that these guidelines are out-dated and clinicians should refer to the dietary reference intakes as published by the Institute of Medicine (Committee to Review Dietary Reference Intakes for Vitamin D and Calcium Food and Nutrition Board, 2011).

Obtaining Vitamin D purely through diet is difficult (Fuller & Casparian, 2001 ; Holick, 2001). In countries where Vitamin D is added to foods (such as in milk in the United States of America, or in table spreads in Australia) (National Health and Medical Research Council, 2014; Nowson & Margerison, 2002), it is assumed that fortification of common dietary components will meet population needs (Glendenning, 2015; Holick, 2001; National Health and Medical Research Council, 2014). However, Nowson et al. (2012) highlights that an estimated 31% of adults in Australia have inadequate vitamin D levels despite fortification. At particular risk are those who are housebound, community dwelling older people, the disabled, those in residential care and those who regularly avoid sun exposure or work indoors .

A group of people who may be at risk of inadequate Vitamin D levels are prisoners (Justice Health, 2009). Sandwell and Wheatley (2009) noted that prisoners spend little time in direct sunlight and there is a lack of oily fish, an easily accessible and known source of vitamin D, offered on prison menus. This raises the question of the prevalence of vitamin D deficiency in prisoners and a possible association with reduced exposure to sunlight. In the United States of America (USA), this hypothesis has been supported by both Jacobs and Mullany (2014) and Nwosu et al. (2014) who both found inadequate levels of Vitamin D in their respective prison populations, particularly those who had spent a longer time in jail overall, or time in medium or maximum security. To date, there are no published data on vitamin D deficiency in Australian correctional facility populations. This study was designed to investigate the association between exposure to sunlight or segregation status and a low vitamin D level in an Australian prison population.

In the non-custodial population, Vitamin D levels have been shown to be significantly below the defined normal range. (Daly et al., 2012; Gillie, 2010; Haines & Park, 2012; Nowson & Margerison, 2002; Nowson et al., 2012; Paxton et al., 2013). This has been attributed to

differing reasons dependent on the location of the study. Gillie (2010) critiques the policy in the United Kingdom of having very few fortified foods, no accepted Vitamin D supplementation policy, and guidelines on sun exposure developed by countries with a higher incidence of clear sunny days. It has been shown that seasonality affects vitamin D levels, with Boyages and Bilinski (2012) showing that levels rise during Summer/Autumn and decrease during Winter/Spring as the body does not have exposure to as many hours of daylight. Studies at psychiatric institutions by Murie, Messow, and Fitzpatrick (2012) have shown that Vitamin D levels are also reduced in those patients who are not exposed to the grounds and thus natural sunlight.

Methodology

Population

The Lithgow Correctional Centre is a high security male correctional facility situated just outside Lithgow on the western side of the Blue Mountains in New South Wales (NSW). Prisoners are seen as required by medical and nursing staff.

All inmates at Lithgow Maximum Security Correctional Centre who had a 25-hydroxy-vitamin D blood test ordered by the visiting medical officers between July 2011 and October 2013 were considered eligible for this study.

Study design, data source and variables

A retrospective cohort was utilised. Eligible subjects were identified by a hand search of pathology records for all patients presenting at the Lithgow Correctional Centre Medical Unit during the study period. The hand search was performed by a single nurse associated with the medical unit who was independent to the study. A case was defined as someone who was vitamin D deficient using the cut off of 50nmol/L recommended by the Endocrine Society of Australia (Nowson et al., 2012). A control was defined as someone with a vitamin D level above 50nmol/L (Glendenning, 2015).

For each eligible subject, study data were extracted from medical, movement, and employment records and recorded onto data collection sheets supplied by the researchers. Demographic data (age (years), ethnicity, height (m), weight (kg)) were collected, along with the following factors considered to affect sun exposure or vitamin D processing: smoking status (y/n), co-morbidities, medications, segregation status, date of vitamin D test, and employment . Additional exposure factors determined for analysis were body mass index (BMI), time in sun (from employment and segregation records), medication count and seasonality.

The primary study exposure factor was spending any time in segregation minimal association (SMAP) as defined by section ten of the Crimes (Administration of Sentences) Act 1999 (NSW Government, 1999). Segregation status was coded as positive for prisoners in segregation minimal association (SMAP). This classification within the prison system is defined as " if in the opinion of the Commissioner that the association of the inmate with other inmates constitutes or is likely to constitute a threat to: (a) the personal safety of any other person, or (b) the security of a correctional centre, or (c) good order and discipline within a correctional centre " (NSW Government, 1999).

Type of employment was used to estimate time in the sun with the assistance of the nurse undertaking the data extraction. The date of the vitamin D test was used to determine season.

A secondary classification of vitamin D status into 3 levels (sufficient, insufficient, deficient) was generated based on the American Endocrine Society clinical practice guideline (Holick et al., 2011) to allow comparisons with similar papers from the USA (Nwosu et al., 2014). Ethnicity was originally classified into 11 categories as recorded in the prison records. This was simplified to four categories similar to the classification used by Nwosu et al. (2014) and Clemens et al. (1982). Reclassification of medications from branded medications into groups based on the indication for the medication (i.e. blood pressure, diabetes, addiction) was undertaken by a medically qualified member of the study team.

Analysis

A single researcher (ZD) entered and coded all study data and performed data cleaning (consistency checked, unknowns coded for, and entry errors identified (Van den Broeck, Argeseanu Cunningham, Eeckels, & Herbst, 2005)). Preliminary descriptive statistics of frequencies for categorical data and means and standard deviations (SD) for continuous data were generated for subject demographic characteristics and study exposure factors for the total study population and by vitamin D status (≤50nmol/L, >50nmol/L).

Associations between study exposure factors and vitamin D status were assessed using odds ratios (OR) and presented with 95% confidence intervals (CI). Binomial logistic regression was undertaken. Where data were not available for an exposure, the participant was excluded from the analysis for that variable. SPSS 23 (IBM Corporation) was used for all analyses. A p-value <0.05 was reported as statistically significant.

The study was approved by the NSW Justice Health and Forensic Mental Health Network Human Research Ethics Committee and The University of Notre Dame, Australia Human Research Ethics Committee.

Results

A total of 124 eligible subjects were identified with a mean age of 43.4 years (SD12.7). Subject demographic characteristics and co-morbidities are summarised in Table 1.

Table 1 Summary of demographic characteristics and comorbidities, 124 subjects

The average vitamin D level across the study population was 55.07 nmol/L (SD 19.8 nmol/L). Just under half (46%, 95% CI 37% – 55%) of the inmates tested were Vitamin D deficient (<50nmol/L). Using the American Endocrine Society classification system, 50 (40%) of the population were vitamin D insufficient (50 to < 75nmol/L), and 20 (16%) were vitamin D sufficient (≤ 75nmol/L). While co-morbidities and medications were intended to be examined the numbers were widely spread, which did not allow for an in depth analysis. There were no significant differences between those who were taking medications and those who were not χ^2 (2, *N=124)* = 2.032, p=0.201, nor those who had co-morbidities and those who did not χ^2 (2, *N=124)* = 0.741, p=0.249 with regards to whether they were Vitamin D replete or not. Analysis of the 10 initial factors (Age, BMI, smoking, ethnicity, season, Vitamin D level, employment, segregation, medications and co-morbidities) was undertaken on raw or aggregated data to determine if the numbers allowed for further analysis. Of the 8 exposure factors which had numbers which allowed for further analysis, smoking (OR 2.93 (95% CI 1.27 – 6.81,p=0.012) and having Asian ethnicity (OR 4.16, 95% CI 1.56 – 11.10, p-value 0.004) were found to be significantly associated with Vitamin D deficiency using Australian cut offs (Table 2).

Table 2 Association between subject characteristics, segregation status, season and vitamin D status, 124 subjects

Discussion

This is the first Australian study of Vitamin D levels in a prison population. We found 46% (95% CI 37-55) of the population selected for testing to be deficient. Our cohort study utilising case control selection limits the interpretation of our findings as prevalence data per se, but our observations broadly correspond with findings in the literature (Jacobs & Mullany, 2014; Nwosu et al., 2014) with regard to risk factors and the fact that the prison population is deficient in Vitamin D. Our findings highlight the need for greater awareness of vitamin D deficiency in prison populations in Australia.

Initially, it was proposed that time in segregation, in particular Segregation Minimal Association [SMAP], as a result of limiting exposure to daylight, would be associated with Vitamin D levels which were not considered replete by the standard measure of greater than 50 nmol/L. Although the current literature suggested this was a likely risk factor (Jacobs & Mullany, 2014; Nwosu et al., 2014) for vitamin D deficiency, our initial analysis showed no significant correlation in our population. Analysis on proxy sunlight exposure measures and other known potential exposures also failed to find any significant differences in vitamin D levels. This finding was unexpected, and even when other significant variables were accounted for, segregation still did not significantly affect vitamin D status. Given the contrast between our data and previous findings, this could be interpreted as a statistical artefact resulting from relatively small case numbers. Also, we were reliant on staff estimates to determine the length of time that a prisoner was subject to segregation, and it is possible that errors in data collection may have limited the accuracy of our analyses. However, another explanation with greater consequences is, perhaps, more likely.

The location of Lithgow correctional centre, being at a higher altitude (950m above sea level) reduces the frequency of sunny days. Weather data shows that Lithgow had a reported average of 139.5 cloudy, and 90.3 clear days per year between 1985 and 2006 versus Sydney Airport which reported 129.2 and and 104.5 days respectively, or further north at Goondiwindi which has 70.5 and 156.8 days. Further west at Perth Airport there is on average a 138.7 clear and 106.9 cloudy days per year. (Commonwealth of Australia, 2015). Cloud cover potentially reduces the amount of UVB light, (Estupiñán, Raman, Crescenti, Streicher, & Barnard, 1996) which in turn influences the production of cutaneous Vitamin D3 in the skin and subsequent production of 25-hydroxy-vitamin D in the liver.(Glendenning, 2015) This may have affected Vitamin D levels derived from UVB across the prison population as a whole, including those inmates who were frequently outside, potentially obscuring the impact of differential access to daylight. This hypothesis is further supported by the fact that time in the sun (as measured through employment and programme participation) also did not correlate with vitamin D status in our study. Movements between prisons, and in and out of the prison system, may also potentially affect the Vitamin D levels of those prisoners under examination; however the Lithgow population by its nature is fairly stable, housing long term maximum-security prisoners.

Location as a key variable has been previously noted by Holick (2006) who, in a review on Vitamin D, notes that latitude, skin pigmentation, body fat, medication use and age may all affect levels.

In our study, BMI, seasonality and age did not correlate with Vitamin D status, but smoking and ethnicity were shown to be significant in initial chi-squared analysis. Ethnicity in particular may be an important factor in further attenuating any potential differences in vitamin D levels relative to a non-custodial population.

While research on vitamin D levels in Australia has been carried out on the general population, as well as specific populations (ambulatory and non-ambulatory hospital patients, those in aged care) (Boyages & Bilinski, 2012), there is no literature on the incidence or occurrence of vitamin D in the prison population, a population which could be considered to be more vulnerable and less likely to have advocates for their health (Justice Health, 2006).

Nwosu et al. (2014) has shown that maximum security prisoners in the USA are at risk of Vitamin D deficiency, despite the fact that many foods within the USA are fortified with Vitamin D, and that ethnicity is a key variable in predicting that risk. Our study has similar results to Nwosu et al., while utilising a case control methodology as opposed to their prevalence study. Our definition of replete and non-replete was also different with Nwosu et al utilising a 3 point scale for Vitamin D of deficient, insufficient and sufficient with the cut offs at <50, 50-75 and >75 nmol/L respectively. In both studies, ethnicity may be acting as a proxy for melanin levels; darker skin, having a greater barrier to UVB, may be less able to synthesise vitamin D in a context where UV irradiation is already low (Norman, 1998). When we ran our data using the same cut offs as Nwosu et al, we still found ethnicity to be a risk factor to Vitamin D deficiency particularly between Asian and the other groupings.

Jacobs and Mullany (2014) also found that prisoners who had been incarcerated for more than a year had significantly lower levels of circulating Vitamin D than a comparison group who had been incarcerated for less than 6 weeks (13.9ng/ml v 25.9ng/ml, $p<0.0001$). They found that after adjusting for BMI and age in unconditional logistic regression modelling the odds for deficiency in their long term group was 18.7 (4.1-84.9). They found race and season of blood draw were not confounders. While we found that season of blood draw did not affect the analysis, race (or in our case ethnicity) was significant. A limitation of the Jacobs and Mullany study was the small group size (29 and 30 for short and long term respectively). Their data collection and analysis did not examine ethnicity nor smoking.

Nowson and Margerison (2002) proposed that in Australia adequate Vitamin D is unlikely to be achieved through dietary means alone, particularly for high risk populations such as those in nursing homes, or for whom sunlight exposure is limited. This is supported by national guidelines which note that institutionalised elderly are shown to have high rates of deficiency (Commonwealth of Australia, 2006). A 2012 position statement shows that most adults in Australia and New Zealand only obtain 5-10% of their Vitamin D from dietary sources, and that the main source of Vitamin D is sunlight (Nowson et al., 2012). They also note that when sun exposure is minimal (such as with those in a custodial population or the institutionalised elderly), that supplementation of 15-20 µg per day based on age is recommended (Nowson et al., 2012). On its own this would not be sufficient to provide adequate Vitamin D but in combination with sunlight and/or supplementation via self-prescribed multi vitamins could potentially provide adequate Vitamin D nutrition (Lu et al., 2007). Multi vitamins and oily fish are available on the “buy up” list, which is a list of available items prisoners can buy with their own money (Corrective Services NSW, 2011a); this may have influenced the relative dietary contribution of vitamin D in our prison population, but we were unable to account for this in our findings. This influence, taken with a brief examination of a typical monthly menu suggest that our prison population may have had a variable oral intake of vitamin D (Corrective Services NSW, 2011b). Given the significance of Vitamin D to health, it would seem prudent to develop policies that monitor Vitamin D intake in prisoners particularly those subjected to periods of segregation.

Smoking was the other significant variable identified in our study. Cutillas-Marco and colleagues found that in a general, non-custodial population in Southern Europe, the odds of

Vitamin D insufficiency in smokers was elevated at 1.8 (Cutillas-Marco, Fuertes-Prosper, Grant, & Morales-Suárez-Varela, 2012), and our results support this finding in our prison population. They also did not find any other mitigating factors such as time in sun, age or skin colour which may confound the increased risk given by smoking. The other prison studies we examined either did not look at smoking as a risk factor (Jacobs & Mullany, 2014) or did not find it to be a risk factor (Nwosu et al., 2014).

A key limitation of our study was that, the case control design based on a retrospective clinical audit, meant that we were dependent on the data which was within the system and its accuracy. Furthermore, testing was for a proportion of selected individuals rather than the population as a whole; hence we cannot use our findings as prevalence data. Our analysis was further complicated by small numbers of cases in our original exposure definition, as well as missing data. Given these restrictions, we frame our findings as indicators of areas of interest for future study rather than as final conclusions.

Conclusions

While research on vitamin D levels in Australia has been carried out on the general population, as well as specific populations (Boyages & Bilinski, 2012), there are no published studies on the incidence or occurrence of vitamin D in a prison population, a population known to be vulnerable and less likely to have advocates for their health (Justice Health, 2006).

We found that there is a small population of prisoners within the Lithgow prison population who are Vitamin D deficient. This suggests that those prisoners who are at risk of Vitamin D deficiency, particularly in a climate where there may be low levels of sunlight, may need to be more closely monitored for sub optimal levels, or even supplied with preventative Vitamin D supplements, to prevent Vitamin D deficiency. The introduction of a non-smoking environment to prisons in NSW in August 2015 may assist in preventing Vitamin D deficiency, but will not be able to be accurately assessed due to comprehensive data on Vitamin D levels not being available prior to the smoking ban.

Further Work

Further work should involve a prospective cohort study of Vitamin D levels in prisoners in other Australian custodial settings. Such work would allow examination of factors such as geography, seasonality and varying management regimes particularly approaches to segregation. An examination of a non-custodial population in Lithgow may also prove valuable in determining if Vitamin D is potentially a regionally based problem, as opposed to a custodial one.

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