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D-lightful sunshine disrupted: Vitamin D deficiency as a method for the reconstruction of changes in sociocultural practices due to industrialisation in 17th - 19th century Netherlands

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Citation

Veselka, B. (2019, January 29). *D-lightful sunshine disrupted: Vitamin D deficiency as a method for the reconstruction of changes in sociocultural practices due to industrialisation in 17th - 19th century Netherlands*. Retrieved from <https://hdl.handle.net/1887/68401>

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Issue Date: 2019-01-29

Summary

This study investigates how vitamin D deficiency assessment can improve our understanding of changes that occurred in sociocultural practices due to industrialisation. The most efficient way of obtaining vitamin D is via dermal synthesis under the influence of ultra-violet B (UVB) radiation in sunlight. The consumption of foods such as oily fish, beef liver, and egg yolk, may provide supplemental amounts of vitamin D. A deficiency in vitamin D will arise if sunlight exposure is inadequate and bending deformities of the skeleton may develop. Vitamin D deficiency is commonly associated with a decrease in sunlight exposure due to the consequences of the Industrial Revolution, such as tall densely-packed buildings and air pollution blocking the sun. Yet, the Netherlands did not experience the Industrial Revolution in the same way as the UK and other western European countries. Therefore, vitamin D deficiency prevalence was not expected to be high in most Dutch communities. However, the 17th to 19th centuries in the Netherlands are characterised by significant economic and political changes, that must have affected all communities and may have had repercussions on health. To assess the influence of these changes on sociocultural practices, this study performed analysis of vitamin D deficiency in six 17th to 19th century Dutch communities, containing a total of 632 individuals, from various settlement types, different geographic locations, all age and sex groups, and socioeconomic statuses (SES).

The first collection is Beemster, which consists of predominantly 19th century skeletal remains from a rural community whose main activities concerned cattle

farming. Archival data reports these individuals to have a middle to low SES. The skeletal collection from this community consists of 95 nonadults (< 18 years) and 200 adults (18+ years). Bloemendaal is the second collection and it consists of 67 adult individuals who were buried in the cemetery next to the psychiatric hospital of Meerenberg, which included patients and staff. This collection dates to the 19th century and historic sources report the majority of these individuals to have had a low SES. The third collection comes from Gouda and consists of 4 nonadults and 45 adults that were excavated inside the Sint-Janskerk dating to the 17th to 19th centuries. Archival data show these individuals had a high SES. The fourth collection is Rotterdam, a large urban centre, which already in the 17th century was an important seaport. The individuals from this collection were buried in the cemetery of the Laurenskerk and date to the 17th century. This collection consists of 3 nonadults and 34 adults. Roosendaal is the fifth collection and comes from the cemetery of the Sint-Janskerk. The skeletal remains date to the 17th to 19th centuries and include 15 nonadults and 45 adults. The main activity of the Roosendaal inhabitants was agriculture and the community had a small-scale textile industry. The last collection, Hattem consists of 28 nonadults and 100 adults dating to the 17th to 19th centuries. The main activity of Hattem was agriculture and the transportation of goods per ship to neighbouring towns and villages.

Relatively high prevalences of rickets were observed in all the communities under study and ranged from 15.3% (9/59) in Beemster to 23.8% (5/21) in Hattem. Results show that in all the communities, the majority of nonadults with active rickets were younger than about 3 years of age, whereas most healing cases were observed in older nonadults. It was postulated that regardless of settlement type, geographic location, occupation, and SES, all nonadults younger than 3 years of age were at risk of developing vitamin D deficiency and not just those from large, industrialised urban centres. After the age of about 3 years, an improvement in sunlight exposure is suggested to have occurred, since most healing cases of rickets were observed after this age. Residual rickets ranged from 12.5% (4/32) in Gouda to 23.9% (21/88) in Hattem, whereby in general, more females were affected than males, which was most clearly visible in Beemster. In this collection, significantly more females (21/100) than males (8/100) were affected. It was postulated that a gendered division of labour increased the risk of developing vitamin D deficiency in Beemster females. Although a gendered division of labour is likely to have existed in the other communities, it may have been less strict and differences between affected females and males per settlement were not statistically significant. Osteomalacia was observed in 1.1% (1/88) of the adult individuals in Hattem, the first general collection to present with adult vitamin D deficiency, excluding Bloemendaal as a psychiatric hospital collection where the risk of osteomalacia development (adult vitamin D deficiency) was expected to be elevated. In Bloemendaal, osteomalacia

was observed in 6.0% (4/67) of the adult individuals. In Hattem, however, the risk of developing osteomalacia was expected to be low, yet one individual displayed adult vitamin D deficiency. Although it is unlikely that osteomalacia was common in Hattem and potentially this individual developed osteomalacia as a secondary condition, changes due to adult vitamin D deficiency are subtler than those of rickets and residual rickets and cases of osteomalacia may have been missed.

A subset of individuals ($n = 30$) from the collection of Beemster and Hattem that displayed macroscopic lesions likely due to rickets and residual rickets were analysed via micro-CT assessment of interglobular dentine (IGD) in the teeth, a microscopic dental mineralisation defect attributed to vitamin D deficiency. This enabled evaluation of the age of vitamin D deficiency onset and provided information on the number of deficient episodes per individual. In addition, thin sections were made from 17 individuals to facilitate comparison between micro-CT and histological analysis of IGD. One tooth was deemed unobservable via micro-CT assessment, and 65.5% (19/29) individuals displayed one or more episodes of IGD. The combined results of micro-CT and histological assessment of IGD show one or more deficient periods in 90.0% (27/30) of the individuals that display macroscopic lesions attributed to vitamin D deficiency. This suggests macroscopic investigation of vitamin D deficiency to be relatively reliable. However, three individuals with macroscopic bending deformities attributed to vitamin D deficiency did not present with IGD and most likely the observed deformities simply represent a more pronounced form of human variation. This study demonstrates micro-CT assessment to be a valuable method that aids in the diagnosis of vitamin D deficiency, whereby individuals with and without clear macroscopic lesions can be assessed for this condition to provide a more accurate overview of vitamin D deficiency prevalence.

In 63.2% (12/19) of the affected individuals, the first visible episode of IGD is present in the layer of dentine formed between 6 and 12 months of age. Furthermore, if IGD is present, it is most frequently observed in this layer of dentine (78.9%; 15/19). The majority of individuals (89.5%; 17/19) did not present with visible IGD after the age of 2.5 to 3 years, which supports the notion that nonadults older than 3 years of age experienced an improvement in sunlight exposure. In three individuals (10.3%; 3/29), the first episode of vitamin D deficiency is observed in the dentine formed around birth, which may be an indication of maternal vitamin D deficiency. No osteomalacia was observed in the females of Beemster or Hattem, yet IGD assessment suggests at least three mothers to have experienced adult vitamin D deficiency. Assessment of IGD can provide information on adult vitamin D deficiency even though macroscopic lesions are not observable. The combined results of micro-CT and histological assessment showed 40.7% (11/27) of the individuals with IGD presented with two or more bands of IGD suggesting vitamin D deficiency was recurrent in both communities. In at least four of them,

the periods were chronologically successive suggesting vitamin D deficiency was seasonal. This is an important finding as clear evidence is presented on recurrent vitamin D deficiency which improves our understanding of the influence seasonality had on communities in more northern latitudes.

Comparison of IGD (number and severity) in Hattem females and males enabled assessment of the influence of sociocultural practices, such as a gendered division in labour. Although Hattem females and males are postulated to have experienced a similar risk in developing vitamin D deficiency, males presented with more severe periods of IGD than females, which may suggest vitamin D deficiency to have been more severe in males. However, the linkages between severity of IGD, macroscopic lesion development, and severity of vitamin D deficiency need further study.

This study demonstrates that the economic and political changes that occurred in the 17th - 19th centuries in the Netherlands, influenced sociocultural practices. Most of these practices are postulated to have been present before the rise of industrialisation and that many wars, general impoverishment, several cattle pests, and crop failures increased pressure on Dutch households to provide for their family's income. This may explain why nonadults aged 3 years and younger are suggested to have been more at risk of developing vitamin D deficiency than the older nonadults. The parents needed to work more and the younger nonadults needed to be kept inside to prevent them from harm, while it is possible that older nonadults could venture outside or even help their parents with various chores. The study of vitamin D deficiency presents information on the influence of sociocultural practices on the prevalence of this condition in past communities, including rural and urban centres thus decreases this paucity in our knowledge. This research stresses the importance of vitamin D deficiency investigation of all past communities regardless settlement size, main occupation, SES, and geographic location.