

Summary

Background:

A principal function of vitamin D is facilitation of intestinal calcium absorption and maintenance of calcium homeostasis. This is essential to several functions in the body, and vitamin D is believed to be particularly crucial during childhood growth as the requirement for calcium increases. In addition to skeletal health, vitamin D has been associated with several extra-skeletal conditions including cardiovascular disease and type II diabetes. Evaluation of Vitamin D status is complex because it is modified by several factors and because the level of optimal vitamin D concentration is uncertain. The primary source of vitamin D in humans is believed to be the synthesis that occurs in the skin upon sun exposure while intake from diet, supplements, and potential fortified foods are secondary sources. Yet, very few foods are rich in vitamin D and little is known on the effect of dietary vitamin D on children's vitamin D status. Synthesis of vitamin D from sun exposure is negligible during winter at northern latitudes such as Denmark, and low winter concentrations have been observed in Danish children. There is a lack of studies investigating vitamin D status in Danish children during times of the year when status is expected to be at its highest. This will elucidate if there are groups of children who are deficient throughout the year and thereby at particular risk of implications from vitamin D deficiency.

The overall aim of the PhD project was to investigate aspects of Danish children's vitamin D status with regard to sufficiency level, possibilities to improve status, and whether status is associated with cardio-metabolic markers.

Method:

The thesis is based on data from the OPUS (Optimal well-being, development and health for Danish children through a healthy New Nordic Diet (NND)) School Meal Study. It was a large cluster-randomized controlled cross-over trial that investigated the impact of NND school meals on dietary intake and nutrient status, growth, early disease risk markers, well-being and absence from school, cognitive function, food waste, and cost as well as social features in 8-11 year-old children. The study was conducted at nine Danish schools and included 834 children in third and fourth grade. For two 3-months periods the children received school meals based on the guidelines of the NND, rich among others in fish, and their habitual lunch in random order. Information on puberty stage, parental education level, demographic background and more was collected before study start. Several measurements were conducted at baseline and at the end of each dietary period. These included

blood samples, DXA scan, anthropometry, 7-day web-based dietary recordings, and 7-day recordings of physical activity. Vitamin D status was assessed as serum 25-hydroxyvitamin D (25(OH)D).

Results:

Baseline 25(OH)D samples were collected from September to November. Serum 25(OH)D concentrations above the appointed sufficiency level of 50 nmol/l were found in 72% of the children during these months while 28% had concentration below. Severe deficiency, characterized as a serum concentration <25 nmol/l, was observed in 2% of the children. Serum 25(OH)D decreased with age, and was lower in children sampled in November, girls, non-white children, and children with immigrant/descendant background, particularly girls. Dietary vitamin D was not associated with baseline vitamin D status, but physical activity, intake of vitamin D containing supplements, and outdoors walking between classrooms during school days were all associated with higher vitamin D status in these autumn months. Data from the school meal intervention was applied to investigate the effect of the NND school meals on the children's vitamin D status. The intervention increased the children's intake of vitamin D by 0.9 µg per day compared to their habitual lunch, but no overall effect of the intervention was found on the children's vitamin D status. Baseline data was applied to investigate the association between vitamin D status and cardio-metabolic markers in the children. Serum 25(OH)D was inversely associated with waist circumference, fasting insulin, total cholesterol, LDL cholesterol, triacylglycerol, diastolic blood pressure, and a score of the metabolic syndrome. The association with diastolic blood pressure, total cholesterol, LDL cholesterol, and triacylglycerol persisted after additional adjustment for BMI, body fat, and physical activity.

Discussion:

We expected a majority of the children to be sufficient at baseline, and were surprised by the high prevalence of vitamin D insufficiency. A priori, we expected variables associated with time spent outdoors to be positively associated with vitamin D status, and we believe that outdoors walks between classrooms and physical activity fall within this category. To our surprise obligatory outdoors recesses were not associated. Yet, the validity of this variable is e.g. questioned by the fact that children may prefer to stay outdoors during recess regardless of it being mandatory or not. It is believed that the lack of effect on the children's vitamin D status from the intervention is due to the small effect on the vitamin D intake. The duration of the intervention period and *ad libitum* approach can among others be discussed, yet, it must be considered that the OPUS School Meal Study did not have vitamin D status as a primary outcome. Although the clinical relevance of the observed associations between vitamin D status and cardio-metabolic markers can be questioned since they

were small and observed in healthy children, the observations do suggest vitamin D status to be inversely associated with a potential detrimental cardio-metabolic profile.

Conclusion:

The data from the OPUS School Meal study allowed an investigation of vitamin D status in Danish children of an extensive magnitude and in a highly representative study sample. More than one fourth of the children had vitamin D concentrations below the acknowledged sufficiency level during autumn. This raises concern as status is expected to decrease further during winter months. The negative determinants, i.e. female gender, immigrant/descendant background, particularly in girls, non-white ethnicity, and age, along with the positive determinants, i.e. physical activity, outdoors walking between classrooms, and intake of vitamin D containing supplements appear appropriate to consider in prevention of vitamin D deficiency in Danish children. Interventions with vitamin D intake are probable to require higher intake of vitamin D than the current school meal study. This, along with the observed associations between vitamin D status and cardio-metabolic markers calls for further investigations.