Journal of Pediatric Nursing 38 (2018) 20–26

Contents lists available at ScienceDirect

Journal of Pediatric Nursing

The Convergence of Two Epidemics: Vitamin D Deficiency in Obese School-aged Children[1]

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ARTICLE INFO

Article history:
Received 29 November 2016
Revised 3 October 2017
Accepted 3 October 2017
Available online xxxx

Keywords:
Vitamin D deficiency
Obesity
Overweight
School-aged children
Children

ABSTRACT

Problem: Vitamin D deficiency (VDD) and obesity are two interrelated global epidemics that affect school-aged children. This article will review the relationship between VDD and obesity in school-aged children and implications it has for the pediatric nurse (PN).
Eligibility criteria: Original articles of studies, review articles and meta-analyses were selected from the past 5 years and pooled for review. These included obese school-aged children who had vitamin D insufficiency. The latest guidelines concerning the issue were also included.
Sample: Children 6–12 years of age with obesity and vitamin D insufficiency.
Results: This review strongly implies obesity in children being a strong risk factor for VDD. Prevention of VDD starts with lifestyle changes and adequate dietary intake of fortified foods and current screening recommendations for VDD are inconsistent. Vitamin D supplementation is recommended with inadequate intake or deficient serum 25-hydroxyvitamin D levels or signs of hypocalcemia. Supplementation doses differ based on whether VDD is being prevented or being treated and in obese children, the Endocrine Society recommends a dose that is two to three times higher than for normal weight children. Subclinical signs and symptoms of VDD include musculoskeletal pain, fractures, reduced bone density and reduced immunity.
Conclusions: Whereas obesity is a strong risk factor for VDD, more research is needed to clarify the role of VDD as a risk factor for obesity.
Implications: The PN plays an essential role in preventing, screening for, assessing for, treating and counseling on VDD in obese school-aged children.

In the face of our current global obesity epidemic (World Health Organization, 2012), we are faced with yet another global epidemic of vitamin D deficiency (VDD). VDD is a worldwide major public health concern across the lifespan (Palacios & Gonzalez, 2014), with children being at greater risk (van Schoor & Lips, 2011). According to the 2001–2006 National Health and Nutrition Examination Survey (NHANES), about one in five children aged 1–11 years have VDD (Mansbach, Ginde, & Camargo, 2009). Suboptimal levels of vitamin D (VitD) affects school-aged children 6–11 years old (73%) more than younger children (63%) (Mansbach et al., 2009). Having sufficient VitD levels in childhood and adolescence is important because osteoporosis risk may be traced back to these periods and bone mass accrual in these periods may be the most important adjustable factor of lifetime bone health (Golden, Abrams, & Committee on Nutrition, 2014). These periods are considered the most important adjustable determinant of future bone health (Golden et al., 2014). Obesity adds another layer of risk for VDD in school-aged children (Turer, Lin, & Flores, 2013). This article will review the relationship between VDD and obesity in school-aged children and implications it has for the pediatric nurse (PN).

Background

In this review, obesity is defined according to body mass index (BMI) parameters established by the Centers for Disease Control and Prevention, where overweight is having a BMI ≥ 85th to <95th percentile and obesity is having a BMI ≥ 95th percentile (Centers for Disease Control and Prevention, 2015). In contrast, the parameters for VDD are less clear, due to differing definitions set forth by the Institute of Medicine (IOM) and Endocrine Society (ES). Table 1 reviews these differences.

1 No specific grant was received from funding agencies in the public, commercial, or not-for-profit sectors. Special thanks to Rita Marie John, CPNP, DNP, EdD and Caitlin Smart, RN, CPNP-PC for personal assistance in manuscript preparation. Conflicts of interest: none.
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https://doi.org/10.1016/j.pedn.2017.10.005
0882-5963/

Table 1
Vitamin D status definitions based on serum 25(OH)D levels.

Status	IOM (IOM, 2011b)		Endocrine Society (Holick et al., 2011)	
	nmol/l	ng/ml	nmol/l	ng/ml
Deficiency	<30	<12	≤50	≤20
Insufficiency	30–49	12–19	52.5–72.5	21–29
Sufficiency	≥50	≥20	≥75	≥30
Reason for concern	>125	>50	–	–

Note. IOM = Institute of Medicine.

Vitamin D Deficiency and Obesity

Obesity and Other Risk Factors for Vitamin D Deficiency

There is strong evidence that obesity is a risk factor for VDD. Being overweight or obese was found to be independently associated with VDD and reduced VitD levels (Gutierrez Medina et al., 2015; Kelly, Brooks, Dougherty, Carlow, & Zemel, 2011; Turer et al., 2013). Turer et al. (2013) evaluated 6–18 year old children enrolled in the 2003–2006 NHANES and found increasingly higher prevalence of VDD with increasing BMI. This study reported that children who were overweight, obese or severely obese (BMI ≥ 99th percentile) were about twice as likely as children of healthy weight to have VDD. Similarly, Vimaleswaran et al. (2013) found that each BMI unit increase correlated with a 1.15% decrease in serum 25-hydroxyvitamin D (25(OH)D) levels. Serum 25(OH)D levels are lower and VitD insufficiency (<30 ng/ml) is more prevalent in obese children when compared to non-obese children (Liu et al., 2016; Motlaghzadeh et al., 2016). Furthermore, Vimaleswaran et al. (2013) found a causal relationship between obesity and reduced serum 25(OH)D (see Table 2). In their sample of 90 obese and non-obese children aged 2–14 years, Motlaghzadeh et al. (2016) administered 50,000 IU of VitD$_3$ once weekly for six weeks. They found a lower therapeutic response in their obese children, which may be due to sequestration of VitD by adipose tissue and decreased serum 25(OH)D bioavailability (IOM, 2011a). In addition to obesity, other risk factors include winter months, darker skin (e.g., African-Americans, Hispanics), use of sunscreen, covered skin, latitude, poverty, and increasing age (Golden et al., 2014; Gutierrez Medina et al., 2015; IOM, 2011a; Kelly et al., 2011; Olson, Maalouf, Oden, White, & Hutchison, 2012; Turer et al., 2013; Vehapoglu et al., 2015).

Effects of Vitamin D Deficiency in Obesity

It has been suggested that VitD may regulate metabolism of adipose tissue (Pyrzak, Witkowska-Sedek, Krajewska, Demkow, & Kucharska, 2015). In a retrospective chart review of 32 obese children with VitD insufficiency who received supplementation, the children had decreased BMI after serum levels reached sufficiency (>30 ng/ml; Grunwald et al., 2017). Suboptimal serum 25(OH)D levels were associated with high adiposity and a two to three times higher risk of being obese (Cediel, Corvalan, Aguirre, de Romana, & Uauy, 2016). Findings were similar in a nationally representative sample of 2492 children from the 2005–2006 NHANES (Moore & Liu, 2016). In contrast, a randomized controlled trial that administered 4000 IU of VitD$_3$ or a placebo daily for six months to 35 obese children with VitD insufficiency found no difference in BMI between the two groups (Belenchia, Tosh, Hillman, & Peterson, 2013). A meta-analysis by Vimaleswaran et al. (2013) also failed to establish a reverse causal relationship between VDD and obesity but found obesity to be a causal risk factor for reduced VitD. While there is evidence for the role of VDD in increasing obesity risk, more studies are needed to clarify this relationship. Details of the reviews and studies discussed here are found in Tables 2 and 3.

VitD more clearly predicts other risk factors of metabolic syndrome (Challa, Makariou, & Siomou, 2015; Ekbom & Marcus, 2016; Erol, Bostan Gayret, Hamilçıkan, Can, & Yiğit, 2017; Kelishadi, Farajzadegan, & Bahreynian, 2014; Liu et al., 2016; Pyrzak et al., 2015). A systematic review by Kelishadi, Farajzadegan et al. (2014) found higher VitD to be associated with healthier lipid profiles in children. VDD was a secondary factor in the development of dyslipidemia (Erol et al., 2017) and those with VDD had higher cholesterol and triglyceride levels (Ekbom & Marcus, 2016; Liu et al., 2016). Reduced VitD levels were also associated with higher blood pressure (Challa et al., 2015; Pyrzak

Table 2
Findings from review articles and clinical guidelines: effects of VDD in obese school-aged children.

First author (year)	Study type	Purpose	Relevant findings
Kelishadi, Farajzadegan (2014)	Systematic review & meta-analysis	Review cross-sectional studies on relation of VitD and lipid profile in children/adolescents	Increased VitD a/w more favorable lipid profile
Vimaleswaran (2013)	Meta-analysis	Explore causality and direction of relation between obesity and VitD using bi-directional Mendelian randomization analysis	Causal relationship between obesity and reduced VitD Any effects of reduced VitD leading to obesity are likely small
Challa (2015)	Review	Review VDD effects on metabolic syndrome	Low VitD increases risk for metabolic syndrome, especially high BP and insulin resistance
Cianferotti (2012)	Review	Review subclinical VDD boundaries, skeletal and extraskeletal effects and supplementation	Extreme VDD presents as rickets and osteomalacia, both rare
Dobnig (2011)	Review	Review skeletal and extraskeletal effects of VDD	Low VitD a/w upper respiratory infections, cardiovascular disease, cancer
Moon (2014)	Review	Review VitD insufficiency effects on bone growth in infancy/childhood	Both fractures and low VitD levels individually common and may coexist Severe VDD → overt rickets, osteomalacia, symptomatic hypocalcemia, all relatively uncommon
Pyrzak (2015)	Review	Review clinical implications of VDD in obese children and adults	Low VitD: risk factor for cardiovascular disorders, metabolic syndrome, hypertension, diabetes, cancer, autoimmune and infectious diseases VitD may promote obesity via adipose tissue regulation
Golden (2014)	AAP clinical report	Update: bone health optimization update	VDD results in rickets in young children (peak 3–18 months) and increases fracture risk in older children
Wagner (2008)	AAP clinical report	Update: VDD and rickets prevention	Low VitD increases PTH, reducing bone mass and increasing fracture risk Clinical signs: abnormal immune function, increasing risk for acute infection and chronic diseases (cancer, psoriasis, diabetes, autoimmune) Extreme VDD → rickets (peak 3–18 months)

Note. AAP = American Academy of Pediatrics. ALP = alkaline phosphatase. a/w = associated with. PTH = parathyroid hormone. VDD = vitamin D deficiency. VitD = vitamin D.