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ORIGINAL PAPER

# Nutritional rickets in Denmark: a retrospective review of children's medical records from 1985 to 2005

**Signe Sparre Beck-Nielsen · Tina Kold Jensen · Jeppe Gram · Kim Brixen · Bendt Brock-Jacobsen**

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**Abstract**
*Introduction* This study describes clinical and biochemical characteristics of nutritional rickets and risk factors at diagnosis among children living in Denmark. All medical records from patients with rickets referred to or discharged from hospitals in Southern Denmark from 1985 to 2005 were identified by register search.
*Materials and methods* Patients included were younger than 15 years of age and fulfilled the diagnostic criteria of primary, nutritional rickets. A total of 112 patients with nutritional rickets were included: 29 were of ethnic Danish origin, and 83 were immigrants.
*Results* Patients diagnosed before the age of 4 (median 1.4) years displayed the classic clinical signs of rickets, whereas patients diagnosed after the age of 4 (median 12.5) years had few clinical signs and unspecific symptoms. Ethnic Danish patients were only diagnosed before age 24 months, and they accounted for 73% of all cases presenting with hypocalcemic seizures, but biochemically, they did not have more severe rickets. Of patients diagnosed before the age of 4 years, 45% were ethnic Danish. In early childhood, insufficient or no vitamin D supplementation was given in 88% of all cases. Among immigrant girls older than 4 years of age, 78% were veiled.
*Discussion* Nutritional rickets in Denmark is predominantly a disease among immigrants, but ethnic Danish patients comprised nearly half of all patients diagnosed before the age of 4 years, and they presented more frequently with hypocalcemic seizures. The main risk factors were omitted, such as vitamin D prophylaxis among the youngest patients and veiling among older children/teenagers.

**Keywords** Danish · Dietary supplements · Vitamin D · Vitamin D deficiency · Rickets · Risk factors

S. S. Beck-Nielsen (✉)
Department of Pediatrics, Hospital of Southwest Denmark,
Finsensgade 35,
6700 Esbjerg, Denmark
e-mail: sbeck-nielsen@health.sdu.dk

T. K. Jensen
Institute of Public Health, Department of Environmental Medicine, University of Southern Denmark,
5000 Odense C, Denmark

J. Gram
Department of Endocrinology, Hospital of Southwest Denmark,
6700 Esbjerg, Denmark

K. Brixen
Department of Endocrinology, Odense University Hospital,
5000 Odense C, Denmark

B. Brock-Jacobsen
Department of Pediatrics, Odense University Hospital,
5000 Odense C, Denmark

**Abbreviation**

| | |
|---|---|
| DNPR | Danish National Patient Registry |
| CPR number | Personal identification number |
| 25(OH)D | 25-Hydroxyvitamin D |
| ALP | Alkaline phosphatase |
| PTH | Parathyroid hormone |
| Ca | Calcium |
| $PO_4$ | Phosphate |
| $1,25(OH)_2D$ | 1,25-Dihydroxyvitamin D |

## Introduction

Rickets is a disease of the growing child caused by defect mineralization of bone matrix [15]. Nutritional rickets is

predominantly seen in the late stages of longstanding vitamin D deficiency but may also be caused by low calcium intake. Several studies of nutritional rickets have been published from developing countries during the last decade [1, 7, 12, 13, 22, 24, 26, 32, 38]. Nutritional rickets, however, has not been eradicated in industrialized countries as reported mainly from North America [8, 11, 14, 17–19, 25, 27, 29, 30, 34, 36].

We undertook this study in order to describe nutritional rickets in an industrialized country as it is characterized at diagnosis in children living in Denmark. Furthermore, we aimed to identify possible risk factors. From this cohort of children with rickets, we have also calculated the incidence of nutritional rickets and the incidence and prevalence of hereditary rickets in Southern Denmark (submitted).

## Materials and methods

Medical records from patients referred to or discharged from hospitals in the former counties of Southern Denmark from 1985 to 2005 with diagnosis codes referring to rickets were reviewed. Medical records with one of the following diagnoses (World Health Organization's *International Classification of Diseases, Revision 8 and 10*) 265, 265.09, 265.19, 265.99, 273.40, DE55, DE55.0, DE55.9, DE64.3, or DE83.3 were identified from hospital registers and in the Danish National Patient Registry (DNPR). DNPR comprises data on all hospitalized patients since 1977 and all outpatient contacts since 1995. All medical records were identified by their unique personal identification number (CPR number) and reviewed by the first author (SBN). Medical records from Southern Jutland County (comprising 19% of the Region of Southern Denmark) were unavailable from 1985 to 1991, as electronic registration was only implemented thereafter.

Patients aged 15 years or more at time of first diagnosis or with non-nutritional rickets were excluded. To verify the diagnosis of nutritional rickets and to exclude hereditary or secondary rickets, the entire medical record(s), including biochemical and radiological investigations, was reviewed. Thus, patients with rickets due to primary or secondary hypophosphatamia, renal insufficiency, liver/bile duct disease, medically induced rickets, malabsorption, enzyme deficiency, or rickets secondary to syndromes were excluded. Patients with serum 25-hydroxyvitamin D (25(OH)D) ≥50 nmol/l were excluded.

The diagnosis was validated upon predefined diagnostic criteria; cases fulfilling both biochemical inclusion criteria and clinical signs/symptoms or radiological signs of rickets were included. In addition, in all patients, the rickets had to heal upon treatment with ordinary vitamin D. Vitamin D insufficiency is defined as serum 25(OH)D <50 nmol/l, vitamin D deficiency as serum 25(OH)D 12.5–25 nmol/l, and severe vitamin D deficiency as serum 25(OH)D <12.5 nmol/l [20]. Biochemical inclusion criteria of nutritional rickets were severe vitamin D deficiency or vitamin D deficiency and at least one of the following: raised plasma alkaline phosphatase (ALP), raised serum parathyroid hormone (PTH), or low serum calcium (Ca) [31]. When no serum 25(OH)D measurements were available, at least one of the following biochemical criteria were fulfilled: raised plasma ALP, raised serum PTH, or low serum Ca. Among infants and young patients, diagnostic clinical signs/symptoms were at least one of following: craniotabes, rachitic rosary, Harrison groove, epiphyseal swelling, bowing of weight bearing extremities, or hypocalcemic seizures [16, 23]. In adolescents, clinical signs/symptoms were at least one of the following: epiphyseal swelling, bowing of legs, muscle weakness, pain of the lower limbs or in the back, or hypocalcemic seizures [23]. Radiological signs were widening of the growth plates with irregularity and cupping of their metaphyseal boarders [31].

Age at diagnosis divided the case series into two groups, infants/young children (0–3.9 years) and older children/adolescents (4–14.9 years), and the patients are subsequently described according to these two age groups. Symptoms, clinical signs, height, weight, and head circumference at diagnosis were recorded. Similarly, we recorded biochemistry, including plasma ALP, serum Ca (total and ionized), plasma phosphate ($PO_4$), serum PTH, serum 25(OH)D, and serum 1,25-dihydroxyvitamin D ($1,25(OH)_2D$) analyzed by the local laboratories. Potential risk factors as breastfeeding without concomitant vitamin D supplementation, omitted vitamin D supplementation, consumption of dairy products, and veiling were recorded if available in the files. Place of birth of the patients and the ethnicity of their parents were determined by inquiry to the Central Office of Civil Registration by use of the CPR number of the patients. Immigrant patients were defined as children of at least one non-Danish parent.

The study was approved by the Ethics Committee of Southern Denmark (M-2678-05) and by the Danish Data Protection Agency.

Statistical analysis was performed using SPSS 15.0. Normally distributed data are presented as mean [95%CI] and skewed data as median [range]. One sample *t* test was used when comparing means, and Mann–Whitney's test was used when comparing skewed variables between groups. In ethnic Danish patients, *z*-scores of height and weight were calculated from growth charts of age and gender-matched Danish children [2] and, similarly, head circumference by age and gender-matched Swedish children [37] by use of the growth calculation program AUXOLOGY®. In immigrant patients aged 0–3.9 years,

*z*-scores were calculated from WHO Child Growth Standards (http://www.who.int/childgrowth/en/, accessed 1st of Oct 2008) by use of the growth calculation program ANTHRO®v2.0.2. In immigrant patients aged 4–14.9 years, *z*-scores were calculated from WHO Child Growth Standards according to the formula in "Computation of centiles and *z*-scores for height-for-age, weight-for-age and BMI-for-age" by WHO (http://www.who.int/childgrowth/en/, accessed 1st of Oct 2008). Normal values for weight-for-age were only available for the age group 5–10 years.

Biochemical findings in patients presenting with generalized seizures were compared to patients without generalized seizures presenting within the same age interval, and biochemical findings in Danish patients were compared to immigrant patients presenting within the same age interval. *P* values <0.05 were considered significant.

## Results

We found a total of 214 medical records with an admission or discharge diagnosis of vitamin D insufficiency or rickets among children younger than 15 years of age in Southern Denmark, which covers a total population of 1.3 million. The diagnosis was validated by review of the medical records using the predefined diagnostic criteria of primary, nutritional rickets whereby 102 cases were excluded (Fig. 1). Of the 112 included patients, 83 were immigrants, and 29 were of Danish ethnicity. Of the immigrants, 44 (53%) were born in Denmark. There was a seasonal variation in diagnosis of nutritional rickets with 84 (75%) cases presented from January to June.

The age at diagnosis occurred in two incidence peaks (Fig. 2). In the group of infants and young children (0–3.9 years, *N*=64), the median age at diagnosis was 1.4 years [0.3–3.6 years]. There was no difference in gender among the young patients. Ethnic Danish patients were all diagnosed between age 5 and 24 months, and they accounted for 53% of patients diagnosed at age 24 months or younger and 45% of all patients 0–3.9 years of age. In the group of older children and adolescents (4–14.9 years, *N*=48), the median age at diagnosis was12.5 years [5.1–14.8 years]. They were all immigrants, and 69% were girls. The diagnosis of rickets was suspected by the referring physician in half of all patients but only in 24% of ethnic Danish patients. In the age group 0–24 months, rickets was an incidental finding during hospitalization for other reasons in 19% of immigrant patients and in 45% of ethnic

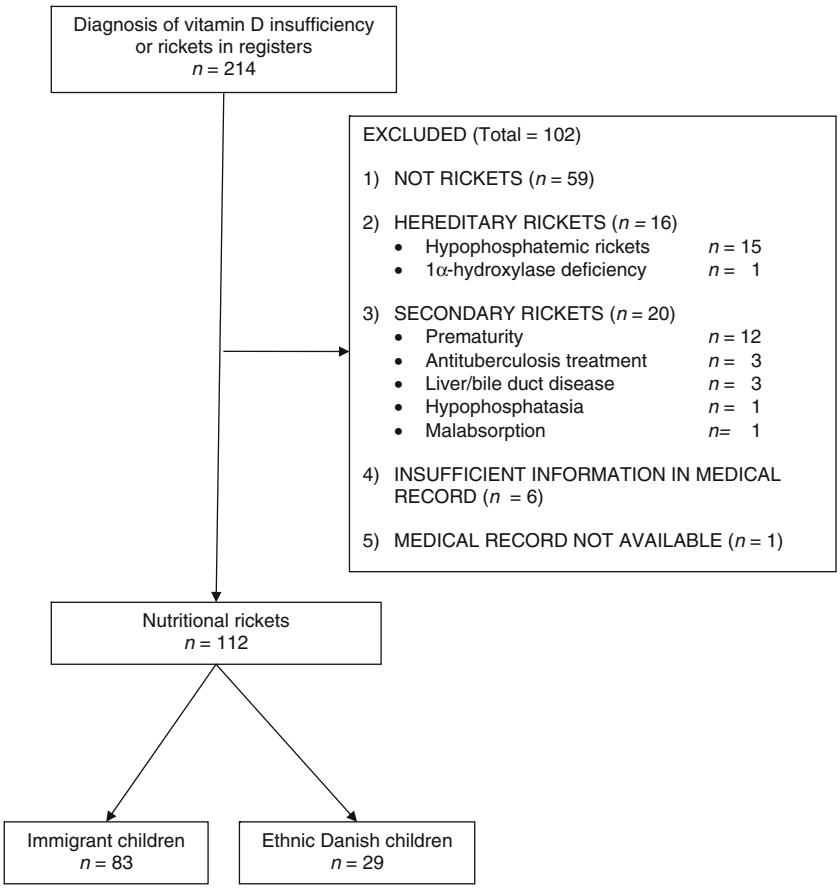


**Fig. 1** Flow diagram of patient inclusion

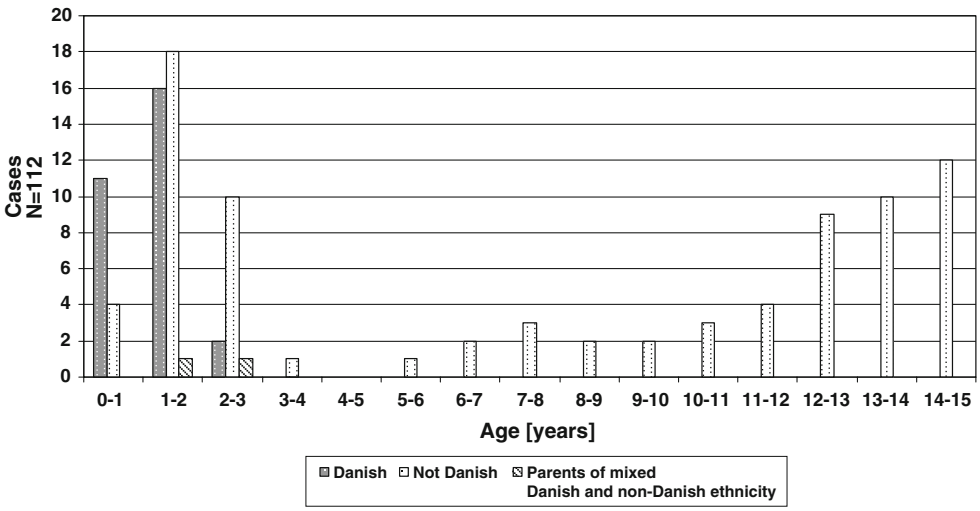


**Fig. 2** Age at diagnosis of nutritional rickets. The age at diagnosis occurred in two incidence peaks, among infants and young children aged 0.3–3.6 years and in older children and adolescents aged 5.1–14.8 years. Remarkably, ethnic Danish children were only diagnosed between age 5 and 24 months

Danish patients. In the remaining cases of this age group, the diagnosis was established at hospitalization.

Among infants/young children (0–3.9 years), the predominant symptom was refusal to support weight on their legs (Table 1). Generalized hypocalcemic seizures were seen in 15 (23%) patients of whom 11 were ethnic Danish. All but one patient with generalized seizures were diagnosed from December to April. Patients with generalized hypocalcemic seizures were diagnosed at a median age of 11 [5–19] months. Their median serum-ionized Ca was 0.83 [0.71–0.95] mmol/l, which was significantly lower ($P<0.0005$) compared to patients without seizures diagnosed from 4 to 19 months of age (Table 2). Regarding plasma PTH and ALP, no statistically significant difference ($P=0.40$) was seen. Radiological evidence of rickets was seen in 75% of patients with generalized hypocalcemic seizures and in 96% of patients without seizures diagnosed from 4 to 19 months of age. There were no statistically significant biochemical differences between ethnic Danish patients and age-matched immigrant patients at diagnosis (data not shown). Fracture was mode of presentation in five patients of whom three were ethnic Danish. The ethnic Danish patients were shorter and thinner than age-matched children, but their head circumference was normal according to age. Immigrant patients of 0–3.9 years of age displayed the same anthropometric characteristics. In the group of older children/adolescents (4–14.9 years; $N=48$), the most frequent symptoms at diagnosis were pain in the back, legs, or generalized skeletal pain. The infants/young children displayed the typical clinical signs of rickets, but among older children/adolescents, few clinical signs of rickets were recorded.

When measured, 97% of the patients had raised plasma ALP, 68% had hypocalcemia, and 92% had hyperparathyroidism. The median serum 25(OH)D was low, 6.0 nmol/l (Table 3). Severe vitamin D deficiency with values of serum 25(OH)D below 12.5 nmol/l was present in 78%. Serum $1,25(OH)_2D$ was below normal in 20%, normal in 60%, and elevated in 20%.

The Danish National Board of Health recommends a vitamin D supplementation of 10 μg/day until 12 months of age in Danish children and until 24 months of age in immigrant children. Among immigrant patients aged 0–3.9 years at diagnosis, vitamin D supplementation was not given in 68%, and all the remaining had vitamin D for a shorter period than recommended or with insufficient compliance (Table 4). Among ethnic Danish patients aged 0–3.9 years at diagnosis, the corresponding numbers were 58% and 32%. The parents of six Danish children reported that vitamin D had been administered according to guidelines, but in all patients, the rickets healed upon treatment with ordinary vitamin D. Data on breastfeeding were available in 45 infants aged 0–3.9 years. Of these infants, 49% were breastfed or weaned within 6 months before the diagnosis of rickets. The duration of breastfeeding among immigrant patients was longer, and 48% received prolonged breastfeeding (>12 months).

Overall, 24% of the patients were on milk-free diet, and 32% consumed less than the recommended 0.5 l/day, which is not fortified with vitamin D in Denmark. Among girls aged 4+ years, 78% were veiled.

## Discussion

This study is the largest case report series of rickets from Europe. Surprisingly, ethnic Danish patients were only diagnosed before 24 months of age. They comprised 53% of all patients diagnosed before 24 months and 45% of all cases among infants/young children (0–3.9 years). This is in contrast to a study of nutritional rickets diagnosed from 1990 to 1999 at three Copenhagen hospitals in Denmark

**Table 1** Symptoms, clinical signs, and growth parameters at diagnosis of nutritional rickets among 112 patients younger than 15 years of age

| | Nutritional rickets | |
|---|---|---|
| | Age 0–3.9 years (*N*=64) Median (range) | Age 4–14.9 years (*N*=48) Median (range) |
| Age (years) | 1.4 (0.3–3.6) | 12.5 (5.1–14.8) |
| Symptoms | *n* (%) | *n* (%) |
| Refuse to support weight on legs | 21 (33) | NA |
| Pain in the legs | NA | 30 (62) |
| Skeletal pain | 0 | 14 (29) |
| Muscle weakness | 1 (2) | 9 (19) |
| Back pain | 0 | 11 (23) |
| Fatigue | 0 | 9 (19) |
| Muscle pain | 0 | 7 (15) |
| Partial seizures | 0 | 3 (6) |
| Generalized seizures | 15 (23) | 1 (2) |
| Clinical signs | *n* (%) | *n* (%) |
| Epiphyseal swelling | 40 (63) | 8 (17) |
| Bowed legs | 33 (52) | 8 (17) |
| Rachitic rosary | 29 (45) | 3 (6) |
| Growth retardation | 25 (39) | 4 (8) |
| Waddling gait | 17 (27) | 5 (10) |
| Delayed motor development | 17 (27) | 0 |
| Caput quadratum | 12 (19) | 1 (2) |
| Craniotabes | 9 (14) | 0 |
| Large fontanel | 8 (13) | 0 |
| Fracture | 5 (8) | 0 |
| Harrison's sulcus | 4 (6) | 0 |
| Chvostek | 0 | 3 (6) |
| Growth parameters (*z*-scores) | Mean (95% CI) | |
| Ethnic Danish patients | | |
| Height for age[a] | −1.5 (−4.4–1.4) [*P*=0.03] | NA |
| Weight for age[a] | −1.3 (−2.9–0.6) [*P*<0.001] | NA |
| Head circumference for age[b] | −0.3 (−1.8–3.5) [*P*=0.52] | NA |
| Immigrant patients | | |
| Height for age[c] | −1.7 (−5.5–1.3) [*P*<0.001] | −0.1 (−2.3–1.4) [*P*=0.5] |
| Weight for age[c] | −0.5 (−3.2–1.6) [*P*=0.06] | −0.8 (−2.3–1.7) [*P*=0.4] |
| Head circumference for age[c] | 0.1 (−1.2–1.7) [*P*=0.86] | NA |

Immigrant patients aged 4–14.9 years: *z*-scores were calculated from WHO Child Growth Standards according to the formula in "Computation of centiles and *z*-scores for height-for-age, weight-for-age, and BMI-for-age" by WHO (http://www.who.int/childgrowth/en/, accessed 1st of Oct 2008). Normal values for weight-for-age were only available for the age group 5–10 years

*NA* not applicable

[a] *z*-Scores of height and weight were calculated from growth charts of age- and gender-matched Danish children [2] by use of the growth calculation program AUXOLOGY®

[b] *z*-Score of head circumference was calculated from growth charts of age- and gender-matched Swedish children [37] by use of the growth calculation program AUXOLOGY®

[c] Immigrant patients aged 0–3.9 years: *z*-scores were calculated from WHO Child Growth Standards (http://www.who.int/childgrowth/en/, accessed 1st of Oct 2008) by use of the growth calculation program ANTHRO®v2.0.2

where the authors only found cases among immigrant patients and concluded that nutritional rickets was a disease only among immigrants in Denmark [25].

Age at diagnosis was clustered around 10–26 months and 12–14 years, which mirrors the greater demands of calcium and phosphate for mineralization of the growing skeleton at periods of high growth velocity. Infants and young children displayed the characteristic clinical signs of rickets, but only approximately 50% had symptoms of rickets possibly due to the inability of children in this age group to express their symptoms. Among older children and adolescents, symptoms were unspecific, and the patients displayed few clinical signs of rickets.

In our study, 23% of the infants presented with generalized hypocalcemic seizures. This symptom was rare among the adolescents, in whom a few cases of partial

**Table 2** Biochemical findings in patients presenting with generalized seizures compared to age-matched patients without seizures

| | Generalized seizures | | No seizures | | *P* value | Reference value |
|---|---|---|---|---|---|---|
| | Median (range) | *N* | Median (range) | *N* | | |
| Age [months] | 11 (5–19) | 15 | 14 (4–19) | 26 | 0.02* | |
| Plasma ALP [U/l] | 1,765 (115–6,368) | 15 | 2,512 (559–10,080) | 22 | 0.24 | 100–400 |
| Serum Ca ionized [mmol/l] | 0.83 (0.71–0.95) | 11 | 1.24 (0.94–1.33) | 14 | <0.0005* | 1.19–1.29 |
| Plasma Ca total [mmol/l] | 1.53 (1.13–2.44) | 13 | 2.3 (1.8–2.63) | 17 | <0.0005* | 2.15–2.70 |
| Plasma PTH [pmol/l] | 23.1 (8.3–81) | 10 | 16.7 (1.3–112) | 13 | 0.42 | 1.1–6.9 |
| Plasma $PO_4$ [mmol/l][a] | 1.59 (1.1–2.06) | 4 | 1.06 (0.57–2.2) | 16 | 0.11 | 1.16–1.81[b] |
| Serum 25(OH)D [nmol/l] | 8 (6–12) | 3 | 4 (4–19) | 5 | 0.57 | 50–178[c] |
| Serum 1,25$(OH)_2$D [pmol/l] | 57 (16–132) | 8 | 187 (29–473) | 7 | 0.15 | 51–177 |

*$P<0.05$

[a] Only patients aged 1–1.6 years since the reference values for plasma $PO_4$ in children 0–1 year are higher

[b] Reference values in children age 1–18 years

[c] Vitamin D insufficiency: serum 25(OH)D<50 nmol/l; vitamin D deficiency: serum 25(OH)D 12.5–25 nmol/l; severe vitamin D deficiency: serum 25(OH)D<12.5 nmol/l [20]

seizures were reported. This difference might reflect the difference in maturation of the brain between infants and adolescents, which is also thought to be responsible for febrile seizures restricted to early childhood. In the Copenhagen study, no convulsions were seen among infants and young patients but only in two peripubertal immigrant patients. It was not specified whether these convulsions were generalized or partial [25]. This case series was smaller and comprised no Danish children, which might explain the few cases of convulsions. Patients with hypocalcemic seizures had lower plasma Ca, tended to have higher plasma $PO_4$ and lower serum 1,25$(OH)_2$D, but they did not have a higher plasma PTH or lower serum 25 (OH)D. This leads to the possibility of some degree of functional hypoparathyroidism present among children developing hypocalcemic seizures. Patients with generalized seizures had less frequently radiological evidence of rickets. In some patients, these seizures might be due to a greater than average initial fall in serum Ca seen in the early stage of rickets before skeletal involvement becomes radiological visible. The interpretation of these results, however, has to be careful considering the small sample size.

Ethnic Danish patients presented more often with hypocalcemic seizures and tended to be more prone to fractures at diagnosis compared to age-matched immigrant patients, but differences in biochemical characteristics did not explain this. However, the possibility of a type two error due to small sample size has to be kept in mind. In a study of vitamin D and bone status among immigrants from Pakistan living in Denmark, the authors found a serum 25 (OH)D below 10 nmol/l in 46% of adolescent Pakistani girls, but only one girl had elevated serum ALP [3]. This study also describes a lower serum 25(OH)D range needed to suppress serum PTH among immigrants from Pakistan compared to similar studies conducted among Caucasians. These results suggest a possible ethnic genetic difference in adjusting to vitamin D insufficiency.

It is remarkable that at time of diagnosis, serum 25(OH) D was assessed in only 41% of the patients and serum 1,25 $(OH)_2$D in 39%, as it is well known that serum 25(OH)D is the best measure for the vitamin D deposits in the body and

**Table 3** Biochemical findings at diagnosis of nutritional rickets among 112 patients younger than 15 years of age

| | Median (range) | Samples | Reference value |
|---|---|---|---|
| Plasma ALP [U/l] | 1,681 (124–10,080) | 104 | 100–400 |
| Serum Ca ionized [mmol/l] | 1.11 (0.6–1.33) | 65 | 1.19–1.29 |
| Plasma Ca total [mmol/l] | 2.13 (1.13–2.64) | 89 | 2.15–2.70 |
| Plasma PTH [pmol/l] | 27.2 (1.3–123) | 74 | 1.1–6.9 |
| Plasma $PO_4$ [mmol/l] (age <1 year, *N*=15) | 1.51 (0.33–2.12) | 12 | 1.36–2.26 |
| Plasma $PO_4$ [mmol/l] (age ≥1 year, *N*=97) | 1.21 (0.51–2.22) | 76 | 1.16–1.81 |
| Serum 25(OH)D [nmol/l] | 6 (3–22) | 46 | 50–178[a] |
| Serum 1,25$(OH)_2$D [pmol/l] | 106 (14–553) | 44 | 51–177 |

[a] Vitamin D insufficiency: serum 25(OH)D<50 nmol/l; vitamin D deficiency: serum 25(OH)D 12.5–25 nmol/l; severe vitamin D deficiency: serum 25(OH)D<12.5 nmol/l [20]

**Table 4** Potential risk factors for nutritional rickets

| Potential risk factor | (*n*/*N*) | Percentage |
|---|---|---|
| Vitamin D supplementation | | |
| Immigrant patients (0–3.9 years)[a] | | |
| Never given | (19/28) | 68 |
| Not given according to recommendations | (9/28) | 32 |
| Ethnic Danish patients (0–3.9 years)[b] | | |
| Never given | (11/25) | 44 |
| Not given according to recommendations | (8/25) | 32 |
| Breastfeeding (0–3.9 years) | | |
| Breastfeed or weaned within 6 months before diagnosis | (22/45) | 49 |
| Breastfeed or weaned within 6 months before diagnosis with no vitamin D supplementation | (19/20) | 95 |
| Breastfeeding in immigrant patients | | |
| Duration of 6–12 months | (20/25) | 80 |
| Prolonged; duration of 12+ months | (11/23) | 48 |
| Breastfeeding in ethnic Danish patients | | |
| Duration of 6–12 months | (9/18) | 50 |
| Prolonged; duration of 12+ months | (0/10) | 0 |
| Milk consumption[c] | | |
| Milk-free diet | (16/68) | 24 |
| Drinking less than 0.5 l of milk/day | (22/68) | 32 |
| Veiling among immigrant girl patients aged (4–14.9 years) | (14/18) | 78 |

*n* number of patients in each category; *N* total number of patients in each category for whom data were available
[a] Danish vitamin D recommendations in immigrant children: 10 μg/day until 24 months of age
[b] Danish vitamin D recommendations in ethnic Danish children: 10 μg/day until 12 months of age
[c] Danish recommendation of milk consumption in children: 0.5 l of dairy products/day

should be first choice of vitamin D metabolites assessed in order to diagnose vitamin D deficiency [21].

There was a seasonal variation in diagnosis of cases, and hypocalcemic convulsions were, with the exception of one case, a presenting symptom only during winter and early spring. Among adults, a seasonal variation in 25(OH)D is described with nadir during winter and early spring [10]. The same variation is most likely seen in children. From October until March, the photo conversion step in vitamin D synthesis cannot take place in Denmark [35], and the vitamin D source in winter is dependent on intake from foods and from supplementation. Seasonal variation in diagnosis of nutritional rickets has been reported from more sunny countries as Canada [34] and Australia [27], and the same variation was present in a study from Tehran from 1975 [28], emphasizing the need for increased oral intake of vitamin D during winter months.

Breastfeeding is not an independent risk factor in developing rickets, but since breast milk is a very poor source of vitamin D, supplementation is essential during exclusive breastfeeding. Vitamin-D-deficient mothers provide only very small deposits of vitamin D to the newborn baby and secrete even smaller amounts of vitamin D in the breast milk further increasing the risk of rickets [4–6, 9, 33]. In our study, breastfeeding was of longer duration among immigrant patients, and 48% received prolonged breastfeeding. Despite the Danish health authority recommendations of vitamin D supplementation of 10 μg/day from age 14 days to 12 months and in immigrants until 24 months of age, nutritional rickets is not eradicated in Denmark. Among the infants and young patients in our cohort, none of the immigrants and only 24% of the Danish patients had received vitamin D supplementation according to guidelines. Among the immigrant patients, 53% were born in Denmark, ensuring that they had been offered visits from a health visitor and preventative health care examinations by their general practitioner. In these cases and among the Danish patients, the preventative visits from the health visitor and the general practitioner failed to discover an inadequate vitamin D intake, or these visits might have been declined. The structure of the Danish health care system has the capacity to ensure adequate vitamin D intake in every child born in Denmark. Increased attention to ensure adequate vitamin D supplementation especially in children of immigrant families, children on prolonged breastfeeding, and children of vitamin D deficient mothers is important in preventing future rickets. In 2005, the guidelines for immigrant children were extended so that vitamin D supplementation of 10 μg/day should be continued throughout childhood. The real challenge in the future is to implement these recommendations despite cultural differences. A possible approach toward elimination of rickets in Denmark may also be the introduction of food fortification with vitamin D, taking ethnic variations in diet into account.

The upper age limit of 0–14.9 years was chosen to limit this study to patients with rickets and to exclude patients with osteomalacia, the adult form of the disease. This study was based on data from retrospectively collected medical records, which implies that the desired data were not always available or reported and that missing observations does not necessarily mean they were not present. Therefore, symptoms and clinical findings may be underestimated in our study. Concerning biochemical characteristics, the availability of data was in part counterbalanced by the number of cases. We presume that the identified cases of nutritional rickets were predominantly vitamin D deficiency rickets, but among patients on milk-free diet and with no measurement of serum 25(OH)D, calcium deficiency rickets cannot be excluded.

The misconception that nutritional rickets in Denmark is an immigrant disease was disproved by our study. The lack of awareness of nutritional rickets as a possible diagnosis among ethnic Danish children implies that Danish patients are clinically more severely affected at diagnosis. Since teenagers display few clinical signs and unspecific symptoms, the indication for screening for vitamin D deficiency must be very liberal among immigrants with risk factors for rickets, especially veiling. The most common risk factor among young children was omitted vitamin D supplementation, and the future challenge will be to prevent nutritional rickets by encouraging parents to follow the vitamin-D-supplementation guidelines.

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