Vitamin D for Growth and Rickets in Stunted Children: A Randomized Trial

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abstract

BACKGROUND AND OBJECTIVES: Vitamin D is essential for healthy development of bones, but little is known about the effects of supplementation in young stunted children. Our objective was to assess the effect of vitamin D supplementation on risk of rickets and linear growth among Afghan children.

METHODS: In this double-blind, placebo-controlled trial, 3046 children ages 1 to 11 months from inner-city Kabul were randomly assigned to receive oral vitamin D3 (100 000 IU) or placebo every 3 months for 18 months. Rickets Severity Score was calculated by using wrist and knee radiographs for 631 randomly selected infants at 18 months, and rickets was defined as a score >1.5. Weight and length were measured at baseline and 18 months by using standard techniques, and z scores were calculated.

RESULTS: Mean (95% confidence interval [CI]) serum 25-hydroxyvitamin D (seasonally corrected) and dietary calcium intake were insufficient at 37 (35–39) nmol/L and 372 (327–418) mg/day, respectively. Prevalence of rickets was 5.5% (placebo) and 5.3% (vitamin D); odds ratio 0.96 (95% CI: 0.48 to 1.92); \( P = .9 \). The mean difference in height-for-age z score was 0.05 (95% CI: −0.05 to 0.15), \( P = .3 \), although the effect of vitamin D was greater for those consuming >300 mg/day of dietary calcium (0.14 [95% CI: 0 to 0.29]; \( P = .05 \)). There were no between-group differences in weight-for-age or weight-for-height z scores.

CONCLUSIONS: Except in those with higher calcium intake, vitamin D supplementation had no effect on rickets or growth.

WHAT’S KNOWN ON THIS SUBJECT: Few trials have been used to examine whether vitamin D supplementation can prevent rickets or improve growth. Vitamin D supplementation potentially prevents rickets in children deficient in vitamin D and increases height in subpopulations of young teenagers and premature infants.

WHAT THIS STUDY ADDS: In a highly stunted population insufficient (not deficient) in vitamin D and calcium using vitamin D supplementation every 3 months, there was no statistically significant reduction in rickets or improved growth. In those with calcium intake >300 mg/day, height improved.


(Continued)
Vitamin D is essential for children achieving optimal linear growth and development of bones. Nutritional rickets is a condition in which there is impaired mineralization of the growth plate and osteoid in a growing child. It can lead to deformities of the lower limbs and pelvis and in severe cases is associated with fragility fractures. Deficiency in vitamin D or dietary calcium intake, or a combination of both these factors, can cause nutritional rickets. Vitamin D deficiency arises when there is inadequate exposure of the skin to sunlight or insufficient dietary intake. Besides being a major cause of rickets and osteomalacia, vitamin D deficiency might also lead to impaired growth. Randomized control trials of vitamin D supplementation revealed improvements in growth in premature low birth weight neonates in India and in school-aged children (11–13 years) in Mongolia. The duration of vitamin D supplementation and follow-up in these 2 trials was only 6 months, and it is not clear whether a longer period of vitamin D supplementation as bolus doses in young children undergoing rapid periods of growth (6–24 months) leads to greater improvements in growth or prevents cases of rickets. Additionally, daily and weekly home supplementation regimens often have poor adherence and bolus doses implemented during regular child health contacts (eg, vaccination) are important supplementation methods for programmatic purposes.

METHODS

Study Design
A more detailed description of the trial methods, including the trial profile, has been published elsewhere. Briefly, this trial was a community-based, double-blind, randomized, placebo-controlled parallel trial that was conducted between November 2007 and June 2009 in 5 inner-city districts of Kabul, Afghanistan. The primary objective of the trial was to evaluate the effect of quarterly supplementation of 100 000 IU (2.5 mg) of cholecalciferol (vitamin D3) on the incidence and/or severity of childhood pneumonia. A priori secondary objectives of the study were to assess the effect of vitamin D3 supplementation on the risk of rickets and linear growth among children.

Intervention
We prepared 2.5 mg of vitamin D3 (cholecalciferol) dissolved in 1 mL of olive oil (vitamin D) or 1 mL of olive oil alone (placebo) in sealed plastic syringes. The vitamin D in olive oil and placebo syringes were identical in appearance, and all families and study personnel, including the clinicians, were blinded to the group allocation of the child. Vitamin D or placebo was given by the field-worker to the child on a quarterly basis; doses were given in November 2007, February 2008, May 2008, August 2008, and December 2008, and the final (sixth) dose was given in March 2008.
mg/day was used as a cut point to Information). Dietary calcium the past week (Supplemental Information). Of the 641 sets of radiographs, 10 could not be evaluated because of reasons such as poor image quality, and so the RSS was available for 631 children (321 in the vitamin D group and 310 in the placebo group).

Measurement of Serum 25(OH)D and Parathyroid Hormone
Five times over the 18 months of the study, ~120 to 140 blood samples (60–70 from the vitamin D group and 60–70 from the placebo group) were randomly collected each time from blocks of children. The timing of the blood samples was to allow for measurement of both the pharmacodynamic and seasonal changes in 25(OH)D concentrations. Serum 25(OH)D was measured by the Immunodiagnostic Systems (IDS)–iSYS multidiscipline automated chemiluminescent assay (IDS Holdings PLC, Tyne and Wear, United Kingdom), and serum intact parathyroid hormone (PTH) was measured by using the IDS intact PTH enzyme-linked immunosorbent assay kit (IDS) at Manchester Royal Infirmary (Supplemental Information).

Power Calculation
The trial sample size was based on the outcome measure of the first episode of pneumonia. Serum concentrations of 25(OH)D and PTH were log transformed to normalize distributions and difference in the geometric mean concentrations between the vitamin D and placebo group were assessed by using linear regression analysis. Logistic regression was used to assess the risk of rickets (RSS >1.5) in the vitamin D compared with the placebo group. The difference in mean RSS and the mean z score of height for age, weight for age, and weight for height was assessed by using multiple linear regression. Heterogeneity in the effect of vitamin D on RSS and anthropometric measurements by the subgroup of calcium intake (<300 mg/day) was assessed by using a standard $\chi^2$ test. This was also done for subgroups of calcium expressed as mg/1000 kcal (<459, ≥459 mg/1000 kcal). In a sensitivity analysis, the between-group differences in the anthropometric z scores were repeated, controlling for the respective baseline values.

All statistical analyses were performed by using Stata statistical software (Stata Corp, College Station, TX, version 15. Two-sided $P$ values <.05 were considered statistically significant.

RESULTS
Characteristics of children for the placebo and vitamin D groups are shown in Table 1. The average age at enrollment was 6 months, and there were slightly more boys than girls in the trial. More than half of the infants were being breastfed at recruitment, and 10% of infants in both the vitamin D and placebo groups were from the poorest households. There was a similar degree of underweight (12%), stunting (13%), and wasting (7%) in the vitamin D and placebo groups. The dietary intake (including breast milk) of energy, protein, and calcium were similar between the groups, and the percentage of children with intakes of calcium

Dietary Intake of Energy, Protein, and Calcium
Twice throughout the study (once in the winter and then in the summer months), mothers (or the main caregiver) completed a semiquantitative food frequency questionnaire (FFQ) that was used to estimate the child’s intake of a list of 56 commonly consumed foods over the past week (Supplemental Information). Dietary calcium <300 mg/day was used as a cut point to define deficiency.6

Adverse Events
There were no adverse events reported in the study. Of the children who had serum concentration of 25-hydroxyvitamin D (25-OH-D) measured, only 5 in the vitamin D and 1 in the placebo group had 25-OH-D >250 nmol/L (indicative of being at risk for hypercalcemia). None of these children had serum calcium measured.

Anthropometry
Measurement of length or height and weight were performed while the children were wearing light or no clothing and were collected from the children at recruitment and 18 months later (Supplemental Information).

Radiographs
There were 641 sets of radiographs of the wrist and knee obtained from a subset of children by use of a simple random sample. The radiographs were evaluated by a consultant pediatric radiologist (M.K.) who was blinded to the group allocation using the RSS for radiologic grading of active nutritional rickets (Supplemental Information). Of the 641 sets of radiographs, 10 could not be evaluated because of reasons such as poor image quality, and so the RSS was available for 631 children (321 in the vitamin D group and 310 in the placebo group).

Statistical Analyses
Of the 3046 children allocated in the trial, anthropometric measurements were available for 2103 children and an RSS score was available for 631 children (Supplemental Fig 3).

Measurements
At recruitment, data on demography, socioeconomic characteristics of the household, and medical history of the child were collected. Principal component analyses of household characteristics and assets were used to measure a wealth index, and this was divided into quintiles as a measure of the socioeconomic status of a household.

Statistical Analyses
Of the 3046 children allocated in the trial, anthropometric measurements were available for 2103 children and an RSS score was available for 631 children (Supplemental Fig 3).
considered deficient (<300 mg/day) was 50.5% and 50.6% in the vitamin D group and placebo group, respectively.

The geometric mean (95% confidence interval [CI]) serum concentrations of 25(OH)D in a random sample of ~120 infants from the placebo and vitamin D groups throughout 5 time points in the study are shown in Fig I. Mean serum 25(OH)D was higher in the vitamin D group compared with the placebo group after the first dose of vitamin D supplement (115 vs 39 nmol/L; \( P < .001 \)), second dose (49 vs 28 nmol/L; \( P < .001 \)), and the third dose (94 vs 47 nmol/L; \( P < .001 \)) of vitamin D supplement. There was no difference in mean 25(OH)D concentration between the vitamin D and placebo group at the last time point (≥4 months after the sixth and final dose of vitamin D). The mean serum 25(OH)D in the subgroup of the placebo group who had 25(OH)D measured was 28 nmol/L in the winter months and 47 nmol/L in summer months, giving a seasonally corrected mean 25(OH)D of 37 nmol/L (95% CI: 35 to 39) throughout the trial period. In the placebo group, 26%, 55%, 55%, 21%, and 7% were <30 nmol/L in rounds 1, 2, 3, 4, and 5, respectively.

Among the placebo group, PTH increased during the winter months (December 2007 to January 2008 and January to February 2008) and was significantly higher than in the vitamin D group at these 2 time points; 2.6 vs 1.8 pmol/L, \( P = .004 \) and 3.8 vs 2.3 pmol/L, \( P < .001 \), respectively (Fig 2). There was no difference in PTH between the placebo and vitamin D group at the other time points.

The proportion of children with an RSS of 0 did not differ significantly between the vitamin D and placebo groups (67% vs 69%), and only one single child in the placebo group had an RSS of 10 (Table 2). The mean RSS, although lower in the vitamin D group, did not differ significantly between the vitamin D and placebo group (0.46 vs 0.35; \( P = .086 \)). The proportion of children with an RSS indicative of rickets also did not differ between the 2 groups (5.5% vs 5.3%; \( P = .9 \)). The mean RSS was lower in the vitamin D group, but this was not statistically significant by intake of dietary calcium.

The mean height-for-age, weight-for-age, and weight-for-height z scores did not differ significantly between the vitamin D and placebo groups for all children and for those with <300 mg/day dietary calcium (Table 3). However, the mean height for age for children with a calcium intake ≥300 mg/day revealed a slight improvement (mean difference 0.14 [95% CI: 0 to 0.29]; \( P = .05 \)); the test for interaction by calcium intake was not statistically significant \( (P = .355) \). Mean height-for-age, weight-for-age, and weight-for-height z scores did not differ significantly between the vitamin D and placebo groups for

**Table 1** Baseline Characteristics of the Children in the Trial by Allocation

<table>
<thead>
<tr>
<th></th>
<th>Placebo (( n = 1522 ))</th>
<th>Vitamin D (( n = 1524 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>780 (51.3)</td>
<td>811 (53.2)</td>
</tr>
<tr>
<td>Girls</td>
<td>742 (48.8)</td>
<td>713 (46.8)</td>
</tr>
<tr>
<td><strong>Child age at recruitment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;2 mo</td>
<td>111 (7.3)</td>
<td>132 (8.7)</td>
</tr>
<tr>
<td>2–5 mo</td>
<td>537 (35.3)</td>
<td>510 (33.5)</td>
</tr>
<tr>
<td>6–12 mo</td>
<td>874 (57.4)</td>
<td>882 (57.9)</td>
</tr>
<tr>
<td><strong>Breastfeeding at recruitment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>865 (56.8)</td>
<td>900 (59.1)</td>
</tr>
<tr>
<td>No</td>
<td>617 (40.5)</td>
<td>584 (38.3)</td>
</tr>
<tr>
<td>Not known</td>
<td>40 (2.6)</td>
<td>40 (2.6)</td>
</tr>
<tr>
<td><strong>Socioeconomic status, fifths</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorest</td>
<td>159 (10.4)</td>
<td>164 (10.8)</td>
</tr>
<tr>
<td>Very poor</td>
<td>266 (17.5)</td>
<td>262 (17.2)</td>
</tr>
<tr>
<td>Poor</td>
<td>247 (16.2)</td>
<td>226 (14.8)</td>
</tr>
<tr>
<td>Less poor</td>
<td>227 (14.9)</td>
<td>226 (14.8)</td>
</tr>
<tr>
<td>Least poor</td>
<td>235 (15.4)</td>
<td>254 (16.7)</td>
</tr>
<tr>
<td>Not known</td>
<td>388 (25.5)</td>
<td>392 (25.7)</td>
</tr>
<tr>
<td><strong>No. indoor smokers in household</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>887 (58.3)</td>
<td>883 (58.6)</td>
</tr>
<tr>
<td>≥1</td>
<td>476 (31.3)</td>
<td>459 (30.1)</td>
</tr>
<tr>
<td>Not known</td>
<td>159 (10.4)</td>
<td>172 (11.3)</td>
</tr>
<tr>
<td><strong>Length-for-age z score</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥–1</td>
<td>918 (60.3)</td>
<td>944 (61.9)</td>
</tr>
<tr>
<td>–2 to &gt; –1</td>
<td>319 (21.0)</td>
<td>301 (19.8)</td>
</tr>
<tr>
<td>&lt;–2</td>
<td>212 (13.9)</td>
<td>200 (13.1)</td>
</tr>
<tr>
<td>Not known</td>
<td>73 (4.8)</td>
<td>79 (5.2)</td>
</tr>
<tr>
<td><strong>Wt-for-age z score</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥–1</td>
<td>969 (63.7)</td>
<td>945 (62.0)</td>
</tr>
<tr>
<td>–2 to &gt; –1</td>
<td>368 (24.2)</td>
<td>372 (24.4)</td>
</tr>
<tr>
<td>&lt;–2</td>
<td>178 (11.6)</td>
<td>185 (12.1)</td>
</tr>
<tr>
<td>Not known</td>
<td>9 (0.6)</td>
<td>22 (1.4)</td>
</tr>
<tr>
<td><strong>Height-for-wt z score</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥–1</td>
<td>1069 (69.6)</td>
<td>1069 (70.1)</td>
</tr>
<tr>
<td>–2 to &gt; –1</td>
<td>288 (19.0)</td>
<td>251 (16.5)</td>
</tr>
<tr>
<td>&lt;–2</td>
<td>98 (6.4)</td>
<td>118 (7.7)</td>
</tr>
<tr>
<td>Not known</td>
<td>76 (5.0)</td>
<td>86 (5.6)</td>
</tr>
<tr>
<td><strong>Daily dietary intake</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy intake, kcal</td>
<td>704.3 ± 326.8</td>
<td>713.4 ± 336.3</td>
</tr>
<tr>
<td>Dietary protein intake, g</td>
<td>212 ± 10.1</td>
<td>215 ± 10.4</td>
</tr>
<tr>
<td>Dietary calcium intake, mg</td>
<td>370.3 ± 272.3</td>
<td>374.3 ± 279.0</td>
</tr>
</tbody>
</table>

All values are \( n \) (%), except when noted otherwise.

* Values are mean ± SD, all such values.

**a** Dietary intake values were available for 1197 in the placebo and 1186 in the vitamin D group.
children with a calcium intake <459 mg/1000 kcal or those with a calcium intake ≥459 mg/1000 kcal (Supplemental Table 4).

It made little difference to the results if the analysis for the anthropometric z scores included an adjustment for baseline values or if growth velocity (centimeter change in height per year) was used (results not shown).

**DISCUSSION**

Six bolus doses of 2.5 mg of vitamin D every 3 months given to young highly stunted children with insufficient vitamin D status and calcium intake did not have a significant effect on the prevalence of rickets over a period of 18 months. There was also no significant effect on growth except in a subgroup with a high intake of calcium.

The lack of an effect of vitamin D supplementation on the risk of rickets in this trial may have been due to several factors. The overall prevalence of rickets at the end of the trial was lower than anticipated (5%), meaning this study may have been insufficiently powered to detect a statistically significant difference between the groups. Nutritional rickets arises when there is inadequate absorption of dietary calcium due to vitamin D deficiency and/or dietary calcium deficiency or when there is vitamin D insufficiency and dietary calcium deficiency.6 These factors result in inadequate dietary calcium absorption leading to a fall in serum calcium, which in turn elevates PTH. This secondary hyperparathyroidism increases renal phosphate wastage, resulting in chronic hypophosphatemia. In a growing child, chronic hypophosphatemia causes rickets through failure of maturation and mineralization of the growth plate, as well as impaired mineralization of osteoid matrix.6,17 High rates (73%) of vitamin D deficiency have previously been reported in young Afghan children,5,14 but in this study, the seasonally corrected mean serum 25(OH)D in the subgroup of the placebo group who had 25(OH)D measured was 37 nmol/L (95% CI: 35 to 39) throughout the trial period; thus, they would be considered vitamin D insufficient rather than deficient. The estimated mean dietary calcium intake in this population was 372 (SD 276) mg/day meaning that this population would be considered insufficient not deficient. Although the mean winter PTH concentrations were not above the assay reference range, some of the children may have developed

![FIGURE 1](image_url)

*Geometric mean (95% CI) serum concentrations of 25(OH)D in the placebo and vitamin D group over the duration of the study. Arrows indicate when the bolus dose of vitamin D or placebo was administered. *P < .001 for difference between placebo and vitamin D.
secondary hyperparathyroidism in the winter months. These findings emphasize the importance of calcium deficiency in combination with vitamin D deficiency or insufficiency in the etiology of rickets.6

There may be other reasons why differences in rickets between groups may not have been detected. A one-year follow-up of Kenyan children who received inpatient treatment of severe acute malnutrition revealed that the presence of rickets (13% of the cohort) was associated with increased linear growth compared with children without rickets.18 Therefore, the impaired growth in this study population, as demonstrated by the high prevalence of stunting, may have contributed to the low rates of rickets irrespective of their level of vitamin D. It is also possible that some features of rickets may be masked in undernourished children. These findings are important for interventions aimed to prevent stunting in LMICs and indicate that for the purpose of growth and rickets prevention, community-level vitamin D supplementation programs alone may not be cost-effective for such populations.

In the few existing trials of vitamin D supplementation for improving growth, results are inconsistent and are not easily comparable to our population. Some reporting a lack of effect of vitamin D supplementation on growth of children may be criticized as being underpowered19 or of insufficient duration.20 Ganmaa et al11 reported an increase in height of almost 1 cm in older school-aged (11–13 years) children in Mongolia.
supplemented with 800 IU (20 μg) of vitamin D plus milk daily for 6 months compared to milk alone and no effect on 9- to 11-year-old children. Kumar et al10 also found no effect on 9- to 11-year-old children. Kumar et al10 also found a greater length-for-age z score in premature low birth weight infants after 6 months of supplementation with 1400 IU/week (35 μg/week) of vitamin D to breast milk compared to breast milk alone. In trials in Mongolia11 and India,10 researchers used daily and weekly supplementation, respectively, whereas in our trial, young children were administered bolus doses of vitamin D every 3 months. Differences in the effectiveness of vitamin D for the daily and weekly versus bolus doses have been described for other outcomes such as acute respiratory tract infections21 and bone outcomes.22 This has been attributed to the finding that high circulating concentrations of 25(OH)D after bolus dosing may downregulate activity of enzymes that synthesize and degrade the active form of vitamin D, 1,25-dihydroxyvitamin D, leading to lower concentrations of this metabolite in extrarenal tissues.23 This in turn may have attenuated the effect of vitamin D on the growth of these young children by reducing intestinal calcium absorption. Other differences in the trial population and design may have contributed to the contrasting findings. Our population is more typical of the highly malnourished populations in LMICs, although the proportion of children who were vitamin D or calcium deficient was low.

Strengths of this trial include being the largest sample size relative to other studies in children, a long follow-up time, vitamin D and placebo supplements being administered to the children directly, radiographic screening of rickets, and use of a validated RSS. The findings are generalizable to Kabul and most of Afghanistan’s urban population. Serum 25(OH)D and PTH were not measured in all children who had radiographic screening for rickets, making it difficult to know whether the cases of rickets were caused by vitamin D deficiency. Serum concentrations of alkaline phosphatase (that are raised above the reference range in rickets) are used as a screening marker for diagnosis of vitamin D deficiency24 but were not measured. Lastly, the relative validity of the FFQ used in this study has not been assessed, and there was no information on the volume and nutritional composition of breast milk from women in Afghanistan, so estimates from Gambian women were used,25 which may have underestimated the contribution of calcium from breast milk, thus reducing the negative effects of vitamin D deficiency.

CONCLUSIONS
Among these young Afghan children who were mostly vitamin D and calcium insufficient, there was no effect of a bolus vitamin D supplementation given every 3 months for 18 months on the risk of rickets and growth except for those who had a high intake of calcium, who had marginally better growth. In future research studies of rickets and growth in undernourished children, researchers need to consider both the vitamin D dosing regimen as well as calcium supplementation.

ACKNOWLEDGMENTS
We thank all the participating families in this study and the project field staff, especially the female Afghan field-workers.

**ABBREVIATIONS**
Cl: confidence interval
FFQ: food frequency questionnaire
IDS: Immunodiagnostic Systems
LMIC: low- and middle-income country
PTH: parathyroid hormone
RSS: Rickets Severity Score
25(OH)D: 25-hydroxyvitamin D

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**TABLE 3 Anthropometric z Scores at 18 Months by Allocation**

<table>
<thead>
<tr>
<th></th>
<th>Placebo (n = 1032), Mean ± SD</th>
<th>Vitamin D (n = 1071), Mean ± SD</th>
<th>Mean (95% CI) Difference</th>
<th>P</th>
<th>P Heterogeneity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height-for-age z score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.355</td>
</tr>
<tr>
<td>All children</td>
<td>−2.21 ± 1.15</td>
<td>−2.16 ± 1.12</td>
<td>0.05 (−0.05 to 0.15)</td>
<td>.300</td>
<td></td>
</tr>
<tr>
<td>Calcium intake &lt;300 mg/d</td>
<td>−2.41 ± 1.14</td>
<td>−2.36 ± 1.08</td>
<td>0.05 (−0.10 to 0.19)</td>
<td>.517</td>
<td></td>
</tr>
<tr>
<td>Calcium intake ≥300 mg/d</td>
<td>−2.12 ± 1.11</td>
<td>−1.98 ± 1.09</td>
<td>0.14 (0 to 0.29)</td>
<td>.050</td>
<td></td>
</tr>
<tr>
<td>Wt-for-age z score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.817</td>
</tr>
<tr>
<td>All children</td>
<td>−1.35 ± 1.00</td>
<td>−1.31 ± 0.95</td>
<td>0.04 (−0.04 to 0.13)</td>
<td>.323</td>
<td></td>
</tr>
<tr>
<td>Calcium intake &lt;300 mg/d</td>
<td>−1.51 ± 0.98</td>
<td>−1.45 ± 0.96</td>
<td>0.06 (−0.07 to 0.18)</td>
<td>.358</td>
<td></td>
</tr>
<tr>
<td>Calcium intake ≥300 mg/d</td>
<td>−1.24 ± 0.98</td>
<td>−1.16 ± 0.93</td>
<td>0.08 (−0.04 to 0.20)</td>
<td>.208</td>
<td></td>
</tr>
<tr>
<td>Wt-for-height z score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.757</td>
</tr>
<tr>
<td>All children</td>
<td>−0.25 ± 0.97</td>
<td>−0.25 ± 0.94</td>
<td>0 (−0.08 to 0.08)</td>
<td>.979</td>
<td></td>
</tr>
<tr>
<td>Calcium intake &lt;300 mg/d</td>
<td>−0.31 ± 0.95</td>
<td>−0.29 ± 0.95</td>
<td>0.02 (−0.11 to 0.14)</td>
<td>.807</td>
<td></td>
</tr>
<tr>
<td>Calcium intake ≥300 mg/d</td>
<td>−0.18 ± 0.93</td>
<td>−0.19 ± 0.93</td>
<td>−0.01 (−0.13 to 0.11)</td>
<td>.846</td>
<td></td>
</tr>
</tbody>
</table>

Height was available for 1029 children in the placebo and 1066 children in the vitamin D group; dietary calcium was available for 907 children in the placebo (n = 443 with calcium <300 mg/day and n = 464 with calcium ≥500 mg/day) and 924 children in the control group (n = 479 with calcium <300 mg/day and n = 445 with calcium ≥500 mg/day).
Drs Walraven, Masher, and Chandramohan made substantial contributions to the conceptualization and design of the study and revised the manuscript critically for important intellectual content; Dr Manaseki-Holland made substantial contributions to the conceptualization and design of the study, directed the study execution, and drafted the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

A deidentified individual participant data set (including data dictionaries) on which the conclusions of the article rely will be made available after publication to researchers who provide a methodologically sound proposal for use. Proposals should be submitted to Dr Crowe (f.crowe@bham.ac.uk).

This trial has been registered at www.clinicaltrials.gov (identifier NCT00548379).

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Vitamin D for Growth and Rickets in Stunted Children: A Randomized Trial
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