Stunting, age at school entry and academic performance in developing countries: A systematic review and meta-analysis

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Research

Keywords: stunting, height-for-age, children, school entry, grade repetition, school dropout, schooling level

Posted Date: June 16th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-606866/v1

Abstract

Introduction

Although many studies have examined the associations between growth problems in infancy and age at school entry, grade repetition, school dropout and schooling level in developing country, no synthesis of the evidence has been conducted. We aim to review evidence of the effects of stunting, or height-for-age, on schooling level and schooling trajectories, defined as the combination of school entry age, grade repetition, and school dropouts.

Methods

We conducted a systematic review of studies (last update March 20, 2021) estimating that estimate the association between stunting, or height-for-age, and at least one component of the school trajectory, or schooling level, using five databases (PubMed, Embase, Education Resources Information Center (ERIC), Web of Science and PsycINFO). Study selection and data extraction were performed by two independent reviewers. Pooled effects were calculated using the generic inverse variance weighting random effect model. The studies' risk of bias was assessed using the ROBINS-I tool for non-randomized studies.

Results

We screened 3944 records by titles and abstracts and retained 16 for inclusion in the qualitative and meta-analysis. Meta-analysis showed that an increase in height-for-age leads to an increase in early enrollment [OR: 1.34 (95% CI: 1.07; 1.67)], a reduction in late enrollment [OR: 0.63 (95% CI: 0.51; 0.78)], an increase in schooling level [MD: 0.24 (95% CI: 0.14; 0.34)], and a reduction of school overage [OR: 0.79 (95% CI: 0.70; 0.90)]. The odds of grade repetition increased by 59% (OR = 1.59; 95% CI: 1.18; 2.14) for stunted children compared to those with no stunting.

Conclusions

This review suggests that stunting in childhood might lead to a delay in school enrollment, grade repetition, school dropout, and low schooling levels in developing countries. Future research should evaluate the effect of stunting on academic trajectories in the same population and explore the potential modification effect of socioeconomic status. The current findings suggest that policy makers need to work more to prevent stunting and to include health issues in educational policies.

Systematic review registration: PROSPERO CRD42020198346

Introduction

In many countries, only a minority of children grow up healthy[1]. The 2018 World Nutrition Report indicates that stunting affects 150.8 million children under five years of age, which represents 22.2% of the world's children[2, 3]. The vast majority of stunted children come from developing countries (148.0 of 150.8 million)[3]. These countries also have more of out-of-school children or people with low academic achievement than the global average. The UNESCO Institute for Statistics reports that, in 2018, 17.7% of children of primary school age were out of school in the least developed countries, compared to only 8.2% globally[4]. In the same year, only 54.0% reached the last grade of primary education in developing countries compared to 81.7% globally[4].

In this context, many studies have been carried out in developing countries on the effects of early childhood development on future academic achievement. These studies have shown that stunting in the first five years of life leads to cognitive impairment in children[5–8], poor school performance, fewer years of schooling, and low productivity in adulthood[7, 8]. Children who have been stunted in childhood are therefore more likely to delay school enrollment, perform poorly in school, repeat a grade, and drop out of school than those who have not been stunted[9, 10]. However, some studies observed no significant association between childhood stunting and academic performance[11, 12], grade repetition[10, 13], and school dropout[14].

Systematic reviews have been undertaken in this field in developing countries. However, most of them[15–20] are qualitative reviews. To our knowledge, only one review[21] carried out a meta-analysis on the effect of linear growth or stunting on child development, but it does not include outcomes on age at school entry, grade repetition, and school dropouts. We aim to review evidence of the effect of stunting or height-for-age on schooling level and schooling trajectories, defined as the combination of school entry age, grade repetition, and school dropouts.

Methodology

The protocol of the review was designed according to the "Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 statement"[22] and registered on the International Prospective Register of Systematic Reviews (PROSPERO) on September

20, 2020 (#CRD42020198346). This review was conducted according to the "Cochrane collaborative guidelines for systematic reviews"[23] and is reported according to "The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions"[24] (see PRISMA check list in Additional file 1).

Eligibility Criteria

The PICOS (Population, Intervention/exposure, Comparator, Outcome and Study design) approach was used to define inclusion criteria. Our population of interest was primary school aged children in developing countries. Generally, the legal age of admission to primary school is between five and seven years old[25]. Primary school usually lasts six years, although it can range from four to seven years[25], and it usually ends between ages 10 and 12 years[25]. We considered studies that include children aged between 5 and 12 years from developing countries. We also included studies on poor child development that resulted in stunting when children were less than five years old. Studies that use standardized height-for-age ratio (height-for-age z-scores) as a measure of child growth during infancy were included. We also considered studies that used height as a marker of stunting. We considered four outcomes: age at school entry, grade repetition, school dropout, and schooling level. Schooling level was defined as the highest level of education attained by an individual at the time of study. Eligible studies were observational studies (prospective, retrospective, case-control, case series, and cross-sectional studies). Studies on diverse populations were included if data on the subgroup of primary school age children related to stunting and outcomes could be extracted or if primary school aged children constituted more than 80% of the study population.

Research Strategy

We conducted a comprehensive systematic literature search via Pubmed, Embase, ERIC (via Ovid), Web of Science and PsycINFO (via Ovid) (last updated March 20, 2021). We developed a rigorous search strategy using relevant keywords related to stunting, schooling trajectory, and geographic area. The search strategy was designed using both free and controlled vocabularies in PubMed, and then translated into other databases. No restriction was applied on language or date of publication. We consulted an information specialist to validate our search strategy, and the sensitivity of the strategy was evaluated by verifying the inclusion of five relevant studies.

Studies management and selection

Data management

The bibliographic reference management software package EndNote was used for citation management. We imported references from databases into EndNote and then removed duplicates using both automatic and manual screening based on study titles. Then, citations were transferred to Covidence for selection.

Study Selection process

Two reviewers (JG and LPB) evaluated all studies independently by screening titles, abstracts, and full texts to identify studies that met the inclusion criteria. We first evaluated inter-reviewer agreement (Kappa) on eligibility using the first 300 citations to ensure that reviewers had a good understanding of inclusion criteria. Inter-reviewer agreements were assessed after each step of selection. Disagreements between JG and LPB were resolved by consensus or by consulting a third reviewer. At the full text stage, reasons for exclusions were recorded.

Data extraction

An Excel data extraction form and a detailed instruction manual was developed and piloted with a sample of three studies. The same two reviewers (JG and LPB) extracted data independently from the selected studies. Data extracted include study characteristics (first author, year of publication, country), population characteristics (sample size, proportion of girls, age), study design, follow-up duration, exposure (type of exposure, age at exposition measurement), outcomes (age at school entry, level of education attained, repetition, dropouts), effect measures, and confidence intervals (adjusted measure of effect, confidence interval, p-value, standard errors, confounding variables). Study authors were contacted with up to three email attempts in case of missing information or unclear data. All extracted data from the two reviewers were cross-checked and disagreements were discussed to reach a consensus or by involving a third reviewer.

Risk of bias

The risk of bias of the included studies was assessed using the ROBINS-I tool for non-randomized studies [26]. The tool covers confounding bias, selection bias, classification bias, bias due to missing data, and bias due to measurement of the outcome. Studies were classified as low, moderate, or high risk. To assess confounding bias, we considered a model well adjusted if it included demographic characteristics (e.g. child sex, child age), and household characteristics (e.g. socioeconomic status, household size, place of residence), and characteristics of the mother and father (e.g. education, size, ethnic group). The same two reviewers (JG and LPB) extracted data on risk of bias evaluation independently. Disagreements were resolved by discussion or by involvement of a third reviewer.

Statistical analysis and data synthesis

Eligible studies were described in detail according to PICOS parameters. We conducted a meta-analysis to estimate the pooled effect of stunting on the different outcomes and their 95% confidence intervals. Then, all studies with sufficient information to estimate the pooled effect were included in the meta-analysis. Pooled effects were calculated according to the domain of the outcome, study design, and effect measured. Thus, for a given outcome domain, more than one pooled effect was estimated if the outcomes were measured in different ways or if different types of effect measures were extracted.

Pooled effects were estimated using generic inverse variance weighting random effect models with Review Manager (RevMan) software [27–29]. Heterogeneity was evaluated by the Higgins I^2 statistic which is the proportion of total variation in the pooled effect size attributable to heterogeneity between studies [30]. Heterogeneity was considered very low, low, moderate, or high if I^2 were, respectively, ≤ 25 %, > 25 % and ≤ 50 %, > 50% and ≤ 75 %, or > 75 % [31, 32]. Sensitivity analyses were performed if heterogeneity was high (I^2>50%).

Sensitivity and subgroup analysis

To understand the source of heterogeneity, a sensitivity analysis was performed by removing one study at a time from the pooled effect size estimation. This allowed us to measure the effect of each selected study on the pooled effect heterogeneity. We were not able to conduct sensitivity analysis on studies at low risk of bias or subgroup analysis based on age of child stunting assessment (≤ 2 years of age and > 2 years of age) due to the insufficient number of studies.

Results

Study selection and characteristics

We identified 4981 studies, of which 3944 were screened by title and abstract after removing duplicates (Fig. 1). Eighty-seven (87) studies were assessed by full text and 16 were considered eligible for the review. From these studies, six were included in the meta-analysis. The inter-reviewer agreements (Kappa statistics) were 97.5% and 83.5% respectively, for title and abstract screening and full-text selection. All studies were in English.

Out of the 16 eligible studies, 7 were published before 2006 [14, 33–38], and 7 others between 2006 and 2015 [6, 7, 12, 39–42] (Table 1 and Table 2). Only two studies were published after 2015 [10, 43]. Most of the studies (56.2 %) used a prospective observational design [6, 7, 10, 12, 14, 36, 37, 41, 42], while 43.8 % were cross-sectional studies [33–35, 38–40, 43]. The most commonly studied exposure was standardized height-for-age (56.2 %) [6, 12, 34, 37, 38, 40, 41] followed by stunting (37.4%) [10, 14, 35, 36, 39]. Two studies [42, 43] used both stunting and height-for-age z-score. Most of the studies analyzed age at school entry [7, 10, 36–42], and schooling level [6, 10, 12, 34, 35, 39, 43]. Relatively few studies analyzed grade repetition [10, 12, 14, 37, 42] and dropout [14, 33, 38]. One study included four countries [6] and another involved two countries [35]. One study presented results only by sex [36]. In Sunny, DeStavola (10), the exposition was measured at three time points (between 0 and 4 months, between 11 and 16 months, and between 4 and 8 years). Sample sizes of included studies ranged from 325 to 2711. Participants were between 6.2 and 18.0 years old at the time of study (Table 2).

Table 1
Characteristics of studies included in the review and meta-analysis

Characteristics	N	%
Characteristics of studies		
Year of publication		
< 2006	7	43.8
2006–2015	7	43.8
> 2015	2	12.4
Study design		
Cross-sectional	7	43.8
Prospective	9	56.2
Retrospective		
Type of exposure*		
Height-for-age z-score	9	56.2
Height	2	12.4
Stunting	6	37.4
Type of outcome domain*		
Age at school entry	9	56.2
Schooling level	7	43.8
Grade repetition	5	31.3
School dropout	3	18.8

*Some studies were counted more than once because they use more than one type of exposition or outcome leading to a number of studies greater than 16 and a total of percentages greater than 100%.

Table 2
Description of included studies and authors' conclusions

Author, year Study design	Setting	Sample size	Age (mean)	Sex (% of girls)	Follow-up duration	Exposure	Outcome domain	Potential confounders considered	Authors' conclusion
Acharya, 2019 [43] Cross-sectional	India	1194	NR	48.6	-	Stunting and Height-for-age between 8 and 11 years	Schooling level	Gender, child's age, child had any chronic illness or congenital or perinatal disorder, mother's education, father's education, child lived with both biological parents in household, household income, scheduled caste/tribe, English medium school, worried about not having sufficient food during the past month	Acute nutritional status was associated with lower math scores and lower educational attainment, suggesting that current adverse conditions are also important determinants of cognitive achievement and educational attainment.
Alderman, 2006 [41] Prospective cohort	Zimbabwe	665	17.7 years	50.8	≈ 14.4 years	Height-for-age at 39.9 months	Age at school entry	Sex, current age, maternal age, maternal education, maternal height, year of first measurement (instrumental variable) exposure to civil a war, drought shock	Improved preschooler nutritional status, as measured by height given age, is associated with increased height as a young adult, a greater number of grades of schooling completed, and an earlier age at which the child starts school
Alderman, 2009 [7] Prospective cohort	Tanzania	≈ 1147	15.7 years	49.0	10 years	Percentage of median reference height at 10 years or less	Age at school entry	Residuals % median, female, age of child in years, mother's height, father's height, parent had secondary schooling, number of teachers per class, number of blackboards per class, urban, maximum education in household, (log) per capita household expenditure, electricity in the household, (instrumental variables) crop loss in 2004, and flood or drought in 2004	Children who are malnourished have lower schooling and delay their school entry.

NR: Not reported

Author, year Study design	Setting	Sample size	Age (mean)	Sex (% of girls)	Follow-up duration	Exposure	Outcome domain	Potential confounders considered	Authors' conclusion
Bogin, 1987 [33] Cross-sectional	Guatemala	514	Range: 7-13.99	NR	-	Height between 7 and 13.99 years	School dropout	Grade, child's age, weight, arm circumference, triceps skinfold, subscapular skinfold, muscle area, and fat area	School continuation or drop-out was not influenced by the health or nutritional environment.
Crookston, 2013 [6] Prospective cohort	Ethiopia India Peru Vietnam	1757 1815 1845 1829	8.1 8.0 7.9 8.1	46.6 46.3 49.8 48.8	7 years	Height-for-age at 1 year	Schooling level	Sex, age of the mother, years of schooling of the mother, years of schooling of the father, asset index, urban residence, community population, community wealth, and presence of a community hospital	Improving growth in children who are stunted in infancy and maintaining nutrition in children who otherwise might falter may have significant benefit for schooling and cognitive achievement.
Daniels, 2004 [36] Prospective cohort	Philippines	2198	18.0 years	47,1	≈ 16 years	Stunting at 2 years	Age at school entry	Parity, maternal and paternal education, maternal height, index of assets, index of environmental cleanliness, presence of electricity, and deflated household income	Boys and girls who were taller at 2 y were markedly less likely to drop out in grade school or to be behind in school and were therefore more likely to graduate from high school on time.
Gandhi, 2011 [12] Prospective cohort	Malawi	325	12.0	51.0	≈ 12 years	Height-for-age at 1 month, residuals height-for-age at 6, 18, and 60 months	Schooling level Grade repetition	Gender, gestational duration, father's occupation, father's literacy, mother's literacy, and wealth index	Height-for-age at 1 month and conditional height gain prior to 6 months did not show significant association with the outcome measures.

NR: Not reported

Author, year Study design	Setting	Sample size	Age (mean)	Sex (% of girls)	Follow-up duration	Exposure	Outcome domain	Potential confounders considered	Authors' conclusion
Glewwe, 1995 [38] Cross-sectional	Ghana	1757	11.0 years	48.2	-	Height-for-age between 6 and 15 years	Age at school entry School dropout	Sex, age, zscore residual, log expenditure/capita, expenditure residual, mother's schooling, father's schooling, number of siblings, ethnic group, residence area, travel time to middle school, travel time to primary school, average teacher experience, average teacher schooling, average teacher training, fraction classrooms with blackboard, books/classroom, fraction classrooms leaking, fraction classrooms unusable, fraction classrooms shed construction, some children lack desks, private school, school has all six grades, enrollment fee, and school denies admission	Delayed primary school enrollment is caused by nutritional deficiencies in early childhood, evidence which survives numerous robustness checks.
Glewwe, 2001 [37] Prospective cohort	Philippines	1016	11 years	48.0	11 years	Height-for-age	Age at school entry Grade repetition	Sex, age enrolled, month of birth effects, (instruments) month of birth, the sibling age difference, and the sibling age and sex differences interacted with the barangay level average grade repetition rate.	Better nourished children perform significantly better in school, partly because they enter school earlier and thus have more time to learn but mostly because of greater learning productivity per year of schooling.

NR: Not reported

Author, year Study design	Setting	Sample size	Age (mean)	Sex (% of girls)	Follow-up duration	Exposure	Outcome domain	Potential confounders considered	Authors' conclusion
Grira, 2004 [34] Cross-sectional	Bangladesh	1338	12.4 years	47.0	-	Height-for-age at 12.4 years	Schooling level	Age, sex, mother's schooling, father's schooling, family size, agricultural land, log income/capita, school flooring type, and school expenses/income	Child health is not significantly determinant to the school enrollment decision, but, once enrolled, nutritional deficiencies substantially retard school progress as they can affect a child's cognitive achievement.
Khanam, 2011 [39] Cross-sectional	Bangladesh	1441	11.2 years	39.0	-	Stunting between 5 and 17 years	Age at school entry, Schooling level	Child's age, gender of child, total household members, log household expenditure, father can read and write, mother can read and write, clean housing condition, sanitary latrine, hand washing, primary school, secondary girls' school, secondary mixed school, distance to doctor, and availability of electricity	Malnourished children are significantly more likely to enroll in school later than the due age. It is also found that, after adjusted for actual enrolled age, the grade attainment of children is not affected by stunting condition.
McCoy, 2015 [40] Cross-sectional	Zambia	2711	6.2 years	48.4	NR	Height-for-age at 6.2 years	Age at school entry	Gender, child age, household size, regional income, and urbanicity	Children's height-for-age at age 6 was significantly predictive of enrollment both concurrently and one year later, suggesting that caregivers (or primary school teachers) may be making decisions about school readiness largely based on their children's physical size.

NR: Not reported

Author, year Study design	Setting	Sample size	Age (mean)	Sex (% of girls)	Follow-up duration	Exposure	Outcome domain	Potential confounders considered	Authors' conclusion
Mendez, 1999 [14] Prospective cohort	Philippines	2131	11.0 years	NR	10 years	Stunting at 2 years	Grade repetition School dropout	NR	Children stunted at age 2 y had a marked delay in initial school enrollment and were much more likely to experience absences and to drop out of school than non-stunted children.
Sunny, 2018 [10] Prospective cohort	Malawi	1044	NR	47.9	11 years	Stunting between, 0 and 4 months, 11 and 16 months, 4 and 8 years	Age at school entry Schooling level Grade repetition	Sex, father's education, mother's education, household asset index at birth	Stunting in early and late childhood was associated with poor school outcomes (late enrollment and poor progression through school).
The Partnership for Child Development, 1999 [35] Cross-sectional	Ghana Tanzania	1566 1390	10.9 years 11.1 years	49.9 52.9	-	Ghana: stunting at 10.9 years Tanzania: stunting at 11.1 years	Schooling level	Ghana: age, Schistosoma haematobium (egg/10 ml) Tanzania: age, sex, socioeconomic status score, school travel time	Children who are stunted are more likely to delay enrollment in school. Delayed enrollment may lead to fewer years of schooling, poor educational achievement and poor employment prospects.

NR: Not reported

Author, year Study design	Setting	Sample size	Age (mean)	Sex (% of girls)	Follow-up duration	Exposure	Outcome domain	Potential confounders considered	Authors' conclusion
Satriawan, 2009 [42] Prospective cohort	Indonesia	1944	Range: 7–9 years	NR	≈ 7 years	Height-for-age and non-stunted	Age at school entry Grade repetition	Time, mother's education, father's education, age of household head, number of 6 to 14 year old children in the household, number of females adult in the household, number of male adults in the household, per-capita expenditure, price of rice, price of sugar, price of cooking oil, price of condensed milk, community fixed effect.	Reducing incidence of poor childhood nutrition reduces also the probability of delayed enrollment, but not the probability of repeating a grade. More importantly, the estimated effects when taking into account the endogeneity of childhood nutrition are 5 to 7 times stronger than when ignoring the endogeneity of childhood nutrition.
NR: Not reported									

Risk of bias

Almost all studies had a moderate (13) or high (2) risk of confounding bias (Table 3 in Additional file 2). More than one-fifth (4, 25%) of studies have a high risk of bias due to missing data. Missing information was not reported in five (31%) studies (Table 3 in Additional file 2). Risks of bias in other domains of bias were low for all studies. Assessment of publication bias by funnel plot was not possible because of low number of studies by outcome of interest and variation in measure of effects estimated.

Stunting and age at school entry

Nine studies presented associations between height-for-age or stunting and an outcome related to age at school entry[7, 10, 36–42]. These studies could not be combined because exposures, outcomes or effect measures differed. Among these studies, one estimated the association between height-for-age at two years and early or late enrollment by sex [36]. The meta-analysis from this study (Fig. 2) suggests that one unit increase in height-for-age is associated with a 34% increase in the odds of early enrollment [OR: 1.33 (95% CI: 1.07; 1.67), I^2=0%] and a reduction of 37% in the odds of late enrollment [OR: 0.63 (95% CI: 0.51; 0.78), I^2=0%]. All studies reported an association between height-for-age or stunting and the age at school entry [7, 10, 36–42] (Table 2 and Table 4 in Additional file 3).

Stunting and schooling level

Two of the four cross-sectional studies[34, 35] assessing the association between height-for-age and school overage by mean difference observed that an increase of one unit of height-for-age in a child was associated with an increase in schooling level for their age. The pooled effect of the studies led to similar results [MD: 0.24 (95% CI: 0.14; 0.34), I^2=92%] (Fig. 3), but was characterized by high heterogeneity. Two other cross-sectional studies were not used in this pooled effect estimation [39, 43]. One [39] found that stunted children were more likely to be overage, and the other reported that stunted children were more likely to be in a low grade; a one unit increase in height-for-age was associated with an increase in grade attainment [43]. In meta-analysis of longitudinal studies, an increase in height-for-age was associated with a reduction in the odds of school overage [OR: 0.79 (95% CI: 0.70; 0.90), I^2=76%] with high heterogeneity. Gandhi, Ashorn (12) and Sunny, DeStavola (10) were not included in the pooled effect estimation because of the analysis methods they used and their outcome measurements. Gandhi, Ashorn (12) reported a non-significant association between height-for-age and schooling level, and Sunny, DeStavola (10) found a significant association (Table 2 and Table 4 in Additional file 3).

Stunting and grade repetition

Figure 4 shows that grade repetition is associated with stunting or height-for-age. All included studies used a longitudinal design. The pooled estimates suggests that the odds of grade repetition increase by 59 % [OR: 1.59 (95% CI: 1.18; 2.14), I^2=51%) for stunted children compared to non-stunted children with moderate heterogeneity. Two studies, which are not include in the meta-analysis, report an association between stunting and grade repetition[12, 37], and one other study did not find an association[42] (see Table 2 and Table 4 in Additional file 3).

Stunting and school dropout

Pooled effects were not estimated for school dropout because no two studies used the same effect measures. Nevertheless, results from these studies were mitigated. Mendez and Adair (14) reported that stunted children were more likely to drop out of school than non-stunted children. But Glewwe and Jacoby (38) found that taller children tended to leave school earlier, while Bogin and MacVean (33) reported that school continuation or dropout was not influenced by health or nutritional environment (Table 2 and Table 4 in Additional file 3).

Sensitivity analysis

The number of studies was not sufficient to conduct sensitivity analyses according to risk of bias or subgroup analyses by age. We performed a sensitivity analysis on schooling level by removing one study or estimated effect at a time from the pooled effect size. When we removed the effect size of Tanzania from The Partnership for Child Development (35) study, the Higgin's I^2 decreased from 90–0% and the magnitude of the pooled effect increased from 0.24 (Fig. 3) to 0.29 (Fig. 5 in Additional file 4).

Discussion

This systematic review suggests that stunting determines age at school entry, schooling level, and grade repetition. An increase one unit in standard deviation in height-for-age is associated with an increase in the odds of early enrollment and delayed enrollment. Children with greater height-for-age were less likely to be overage for their grade. We also found that stunted children were more likely to repeat a grade than nonstunted children. Results from this study do not allow conclusions to be drawn regarding the relationship between stunting or height-for-age and dropping out of school.

Childhood stunting can be associated with difficulties learning the school curriculum. Children with high height-for-age z-scores, or those who were non-stunted started school earlier than those with low height-for-age z-score or those who were stunted. The latter are considered unready to start school at the minimum enrollment age [7, 37, 44]. Delayed enrollment could also reflect a filter imposed by schools if administrators use height as a sign of school readiness [7]. The high probability of grade repetition for stunted children is due to low school performance. Grade repetition occurs when children's academic performance is deemed unsatisfactory. Schooling levels can be seen as the reflection of age at school enrollment and grade repetition, and are thus dependent on academic performance. Several studies have highlighted that stunted growth and height-for-age are associated, respectively, negatively and positively with test results in mathematics, reading, communication and motor development [6, 21, 45–49]. Results showed that impaired growth and development in infancy negatively affects later academic performance and therefore academic trajectory, which leads, overall to low school levels. This may explain why stunted children are more likely to be unemployed, less productive, and to have low social status than non-stunted children[50–53].

Stunting could lead to a delay in the development of cognitive functions and permanent cognitive impairments, which improve little with age[54]. This relationship between stunting and cognitive abilities is particularly important in the first years of life when vital human development occurs in all domains, including the brain formation[16, 55]. When stunting occurs in this early stage of life, it severely affects attention development, executive functions such as cognitive flexibility, working memory, and visuospatial functions like visual construction[54]. Experimental research on animals has also shown that nutrition deficiencies negatively affect brain development and measure of performance[55–58], but it is difficult to extrapolate this to human cognition[57]. Thus, to establish causality between nutritional status and performances, intervention studies has been undertaken, and they have shown that early intervention on health and nutrition increase child probability to be enrolled on time in primary school, and improve cognitive development [15, 59].

Strengths and limitations

This review is one step towards better understanding the effects of growth in early childhood on subsequent school trajectories. It is the first review to highlight the components of the academic trajectory that are influenced by stunting. This review does have some weaknesses, however. First, almost all studies were identified as having moderate risk of confounding bias, even though some of them used advanced methods to control for confusion. This is due to the tool of bias assessment. Second, outcomes and measures of effect varied widely across studies, which limited our ability to estimate pooled effects. However, this diversity allowed us to explore multiple facets of academic performance. Third, we did not obtain sufficient data to estimate pooled effects of stunting or height-for-age on dropouts, which suggests that this outcome has not been sufficiently studied in the literature. Fourth, due to the low number of studies, we were not able to perform subgroup analysis which may have shown an effect of the timing of stunting (e.g., stunting before 2 years vs stunting after 2 years).

Conclusion

The results show that stunting in childhood might lead to a delay school enrollment, grade repetition, school dropout and low schooling levels. This study is a step towards understanding the overall effect of stunting or height-for-age on academic trajectory. Results showed that impaired growth and development in infancy is associated with a delay of school age entry, an increased risk of grade repetition, and increased school dropout, which, in turn, lead to children's low levels of education. Although this review provides an overall picture of the educational trajectory of children from developing countries who experienced stunting in childhood, further research is needed on the effect of stunting on educational trajectories among this population. Since stunting affects more children from poor communities than from wealthy communities, future research should also explore the effect modification of socioeconomic status on the relationship between stunting and school trajectories to inform the development of effective interventions. The current results imply the need for leaders of developing countries to work more for the prevention of stunting through programs and projects focused on nutrition and health problems in childhood. Similarly, health issues should be integrated into education policies to allow for specific care of stunted children in order to improve their school performance.

Abbreviations

PROSPERO
International Prospective Register of Systematic Reviews
PRISMA-P
Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols
OR
Odds Ratio
MD
Mean Difference
RevMan
Review Manager
PICOS
Population, Intervention/exposure, Comparator, Outcome and Study Design

Declarations

Ethics approval and consent to participate

Not Applicable

Consent for publication

Not Applicable

Availability of data and materials

Not Applicable

Competing interests

The authors declare that they have no competing of interests

Funding

This research has no source of funding.

Authors' contributions

RJG, SH, and LM conceived the study. RJG drafted the protocol and LM revised it. RJG and LPB selected studied and extracted data. SH intervened to settle disagreements. RJG wrote the first draft of the manuscript, which was revised by LM and JFK. The final manuscript was read and approved by all authors.

Acknowledgements

Not Applicable

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Figures

Figure 1

Study selection process for the review * Kappa for screening by title and abstract = 97.5% ** Kappa for selection by full text = 83.5%

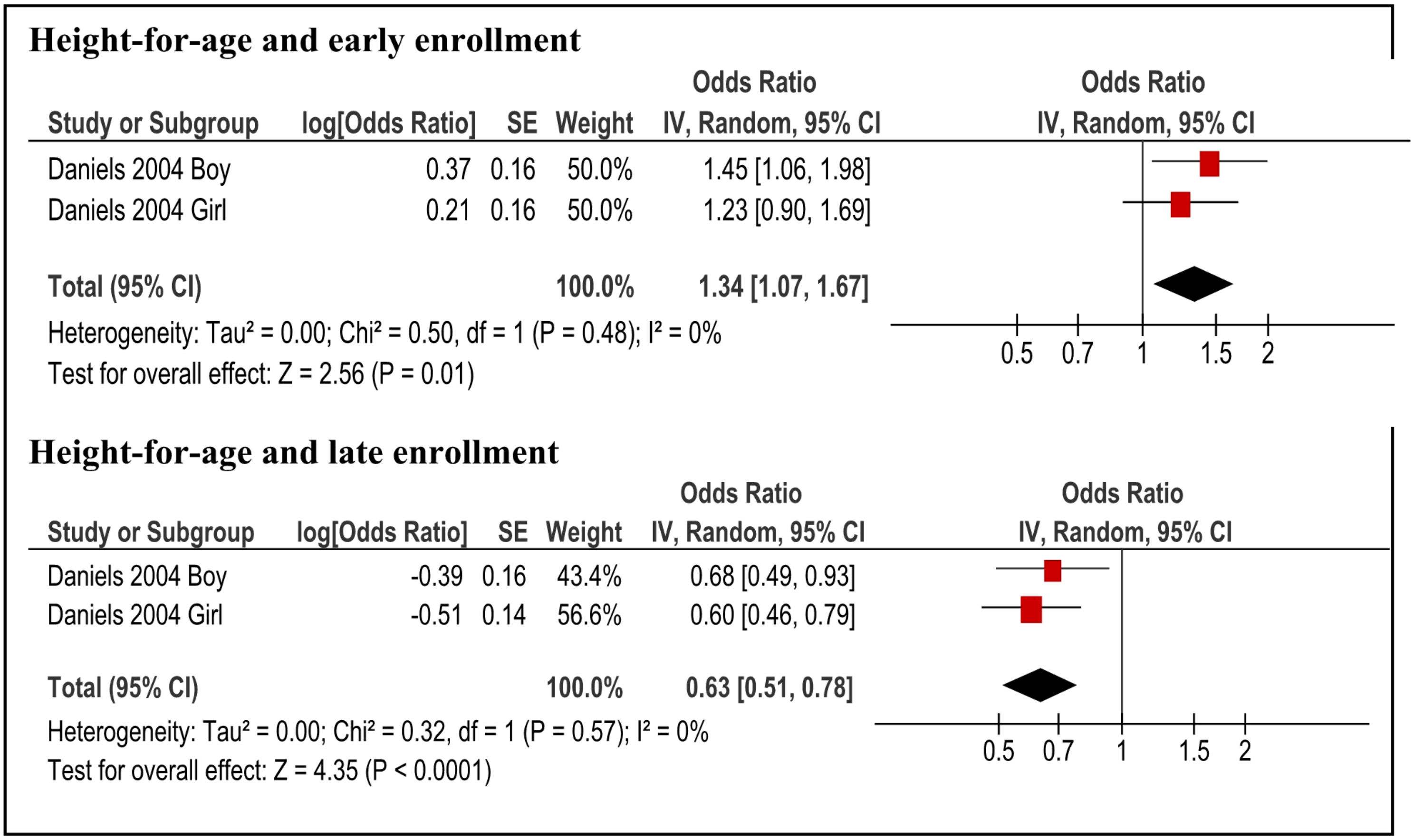

Figure 2

Meta-analysis of the association between height-for-age and early or late enrollment

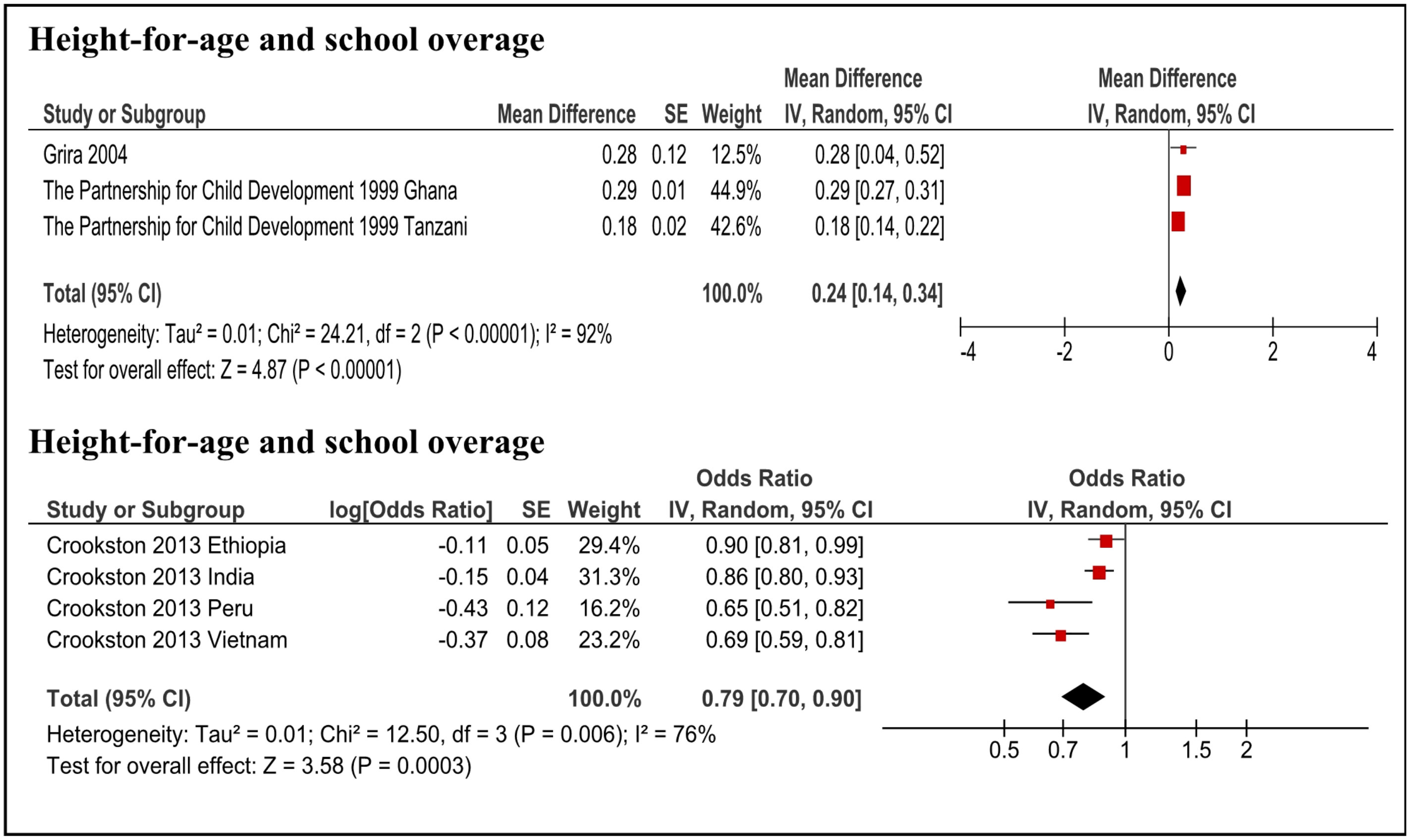

Figure 3

Meta-analysis of the association between height-for-age and schooling level

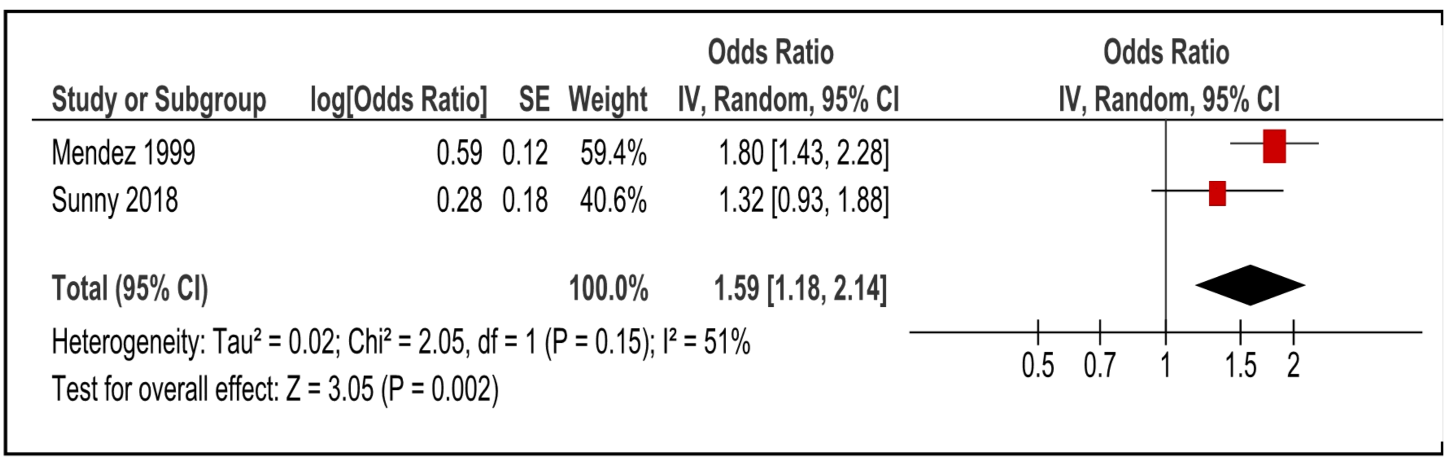

Figure 4

Meta-analysis of the association between height-for-age and grade repetition

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