INTRODUCTION

In many countries, only a minority of children grow up healthy. 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. The vast majority of stunted children come from developing countries (148.0 of 150.8 million). These countries also have more out-of-school children or people with low academic achievement than the global average. The United Nations Educational, Scientific and Cultural Organization (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 with only 8.2% globally. In the same year, only 54.0% reached the last grade of primary education in developing countries compared with 81.7% globally.
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, poor school performance, fewer years of schooling, and low productivity in adulthood. Children who have been stunted in childhood are therefore more likely to delay school enrolment, perform poorly in school, repeat a grade, and drop out of school than those who have not been stunted. However, some studies observed no significant association between childhood stunting and academic performance, grade repetition, and school dropout.

Systematic reviews have been undertaken in this field in developing countries. However, most of them are qualitative reviews. To our knowledge, only one review 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 the 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.

1.1 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’ and registered on the International Prospective Register of Systematic Reviews (PROSPERO) on 20 September 2020 (#CRD42020198346). This review was conducted according to the ‘Cochrane Collaborative Guidelines for Systematic Reviews’ and is reported according to the PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions.

1.2 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 5 and 7 years. Primary school usually lasts 6 years, although it can range from 4 to 7 years, and it usually ends between ages 10 and 12 years. 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 5 years old. Studies that use standardised height-for-age ratio (height-for-age z-scores) as a measure of child growth during infancy were included. Height-for-age z-score is a number of standard deviations of height below or above the median reference value.

According to the World Health Organization (WHO), a child is stunted when his or her height-for-age is below −2 standard deviations. 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.

1.3 Research strategy

We conducted a comprehensive systematic literature search via PubMed, EMBASE, ERIC (via Ovid), Web of Science and PsycINFO (via Ovid) (last updated 20 March 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.

1.4 Study management and selection

1.4.1 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.

1.4.2 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.

1.5 | Data extraction

An Excel data extraction form and a detailed instruction manual were 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.

1.6 | Risk of bias

The risk of bias of the included studies was assessed using the ROBINS-I tool for non-randomised studies.28 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), 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.

1.7 | 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.29–31 Heterogeneity was evaluated by the Higgins I² statistic, which is the proportion of total variation in the pooled effect size attributable to heterogeneity between studies.32 Heterogeneity was considered very low, low, moderate, or high if I² were, respectively, ≤ 25%, > 25% and ≤ 50%, > 50% and ≤ 75%, or > 75%.33,34 Sensitivity analyses were performed if heterogeneity was high (I² > 50%).

1.8 | 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 the age of child stunting assessment (≤ 2 years of age and > 2 years of age) due to the insufficient number of studies.

2 | RESULTS

2.1 | Study selection and characteristics

We identified 4981 studies, of which 3944 were screened by title and abstract after removing duplicates (Figure 1). Eighty-seven (87) studies were assessed by full text, and 16 were considered eligible for the review. Of 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 2006,14,35–40 and 7 others between 2006 and 2015 (Table 1; Table S1).6,7,12,41–44 Only two studies were published after 2015.10,45 Most of the studies (56.2%) used a prospective observational design,6,7,10,12,14,38,39,43,44 while 43.8% were cross-sectional studies.35–37,40–42,45 The most commonly studied exposure was standardised height-for-age (56.2%)6,12,36,39,40,42,43 followed by stunting (37.4%).10,14,37,38,41 Two studies44,45 used both stunting and height-for-age z-score. Both height-for-age and stunting were calculated based on the 2006 World Health Organization (WHO) reference population in 5 studies,6,10,12,42,45 Two studies14,38 published before 2006 also used the WHO reference population. Center for Disease Control and Prevention (CDC) and National Center for Health Statistics (NCHS) reference populations were used respectively for Satriawan44 and the Partnership for Child Development37 studies. The American reference population was used in 2 studies.39,40 Grira36 and Khanam et al.41 used respectively WHO/NCHS/CDC and WHO/NCHS as reference populations. Most
of the studies analysed age at school entry\textsuperscript{7,10,38–44} and schooling level.\textsuperscript{6,10,12,36,37,41,45} Relatively few studies analysed grade repetition\textsuperscript{10,12,14,39,44} and dropout.\textsuperscript{14,35,40} One study included four countries,\textsuperscript{6} and another involved two countries.\textsuperscript{37} One study presented results only by sex.\textsuperscript{38} Sunny et al.\textsuperscript{10} measured the exposition 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 S1).

\subsection*{2.2 Risk of bias}

Almost all studies had a moderate\textsuperscript{13} or high\textsuperscript{2} risk of confounding bias (Table S2). We were unable to assess the risk of confounding bias in one study because the confounding variables were not specified, and the author did not respond to our request for clarification. 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 S2). 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.

\subsection*{2.3 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.\textsuperscript{7,10,38–44} 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 2 years and early or late enrolment by sex.\textsuperscript{38} The meta-analysis from this study (Figure 2) suggests that one unit increase in height-for-age is associated with
a 34% increase in the odds of early enrolment [OR = 1.33 (95% CI, 1.07–1.67), \( I^2 = 0\% \)] and a reduction of 37% in the odds of late enrolment [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 (Tables S1 and S3).7,10,30–44

2.4 | Stunting and schooling level

Two of the four cross-sectional studies36,37 assessing the association between height-for-age and school overage by mean difference observed that an increase in 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), \( I^2 = 92\% \)) (Figure 3) but was characterised by high heterogeneity. Two other cross-sectional studies were not used in this pooled effect estimation.41,45 One41 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.45 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 et al.12 and Sunny et al.10 were not included in the pooled effect estimation because of the analysis methods they used and their outcome measurements. Gandhi et al.12 reported a non-significant association between height-for-age and schooling level, and Sunny et al.10 found a significant association (Tables S1 and S3).

2.5 | 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 suggest 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 included in the meta-analysis, report an association between stunting and grade repetition,12,39 and one other study did not find an association (see Tables S1 and S3).44

2.6 | 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 Adair14 reported that stunted children were more likely to drop out of school than non-stunted children. Yet, Glewwe and Jacoby40 found that taller children tended to leave school earlier, while Bogin and MacVean35
reported that school continuation or dropout was not influenced by health or nutritional environment (Tables S1 and S3).

2.7 | 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 study, the Higgin's $I^2$ decreased from 90% to 0% and the magnitude of the pooled effect increased from 0.24 (Figure 3) to 0.29 (Figure S1).

3 | DISCUSSION

This systematic review suggests that stunting determines age at school entry, schooling level and grade repetition. An increase in one unit in standard deviation in height-for-age is associated with an increase in the odds of early enrolment and delayed enrolment. 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 non-stunted 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 enrolment age.\textsuperscript{7, 21, 49–53} Delayed enrolment could also reflect a filter imposed by schools if administrators use height as a sign of school readiness.\textsuperscript{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. This probability would be even higher if stunted children lived in poor households. Indeed, previous studies show that children from poor households perform less well in school\textsuperscript{48} because they are put to work to contribute to the family income.\textsuperscript{48}

Schooling levels can be seen as the reflection of age at school enrolment 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.\textsuperscript{6, 21, 49–53} Results showed that impaired growth and development in infancy negatively affect 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 and less productive, and to have low social status than non-stunted children.\textsuperscript{54–57}

Stunting could lead to a delay in the development of cognitive functions and permanent cognitive impairments, which improve little with age.\textsuperscript{58} 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.\textsuperscript{16, 59} 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 such as visual construction.\textsuperscript{58} Experimental research on animals has also shown that nutrition deficiencies negatively affect brain development and measure of performance.\textsuperscript{59–62} but it is difficult to extrapolate this to human cognition.\textsuperscript{51} Thus, to establish causality between nutritional status and performances, intervention studies have been undertaken, and they have shown that early intervention on health and nutrition increases child probability to be enrolled on time in primary school, and improves cognitive development.\textsuperscript{15, 63}

3.1 | 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). Fifth, the fact that height-for-age z-score or stunting was measured on the basis of different reference populations may be a source of heterogeneity in the effect measure.

4 | CONCLUSION

The results show that stunting in childhood might lead to a delay in school enrolment, 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 are 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 programmes 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.

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CONFLICT OF INTEREST
The authors declare that they have no competing interests.

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