Original Article

Effects of nutritional interventions on the physical development of preschool children: a systematic review and meta-analysis

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Background: There is a significant correlation between diet and delayed growth and development in children. However, the evidence for the crucial role of dietary interventions in children's growth and development health remains inconclusive. This meta-analysis sought to comprehensively evaluate the effects of nutritional interventions on children's physical development.

Methods: Articles published from January 2007 to December 2022 were retrieved from the PubMed, Embase, Cochrane Library, Wanfang, and China National Knowledge Infrastructure (CNKI) databases. Statistical analysis was conducted using Stata/SE 16.0 software, as well as Review Manager 5.4 software.

Results: The meta-analysis included a total of 8 original studies. The total sample comprised 6,645 children aged <8 years. The results of meta-analysis were as follows: (I) there was no significant difference in the body mass index (BMI)-for-age z scores between the nutritional intervention group and the control group [mean difference (MD) =0.12, 95% confidence interval (CI): –0.07, 0.30]. Thus, the nutritional interventions did not significantly improve the BMI-for-age z scores; (II) when the nutritional intervention period was <6 months, there was no significant difference in the weight-for-height z scores between the nutritional intervention group and the control group (MD =0.47, 95% CI: –0.07, 1.00), but when the nutritional intervention period was ≥6 months, the nutritional interventions significantly improved the weight-for-height z scores (MD =0.36, 95% CI: 0.00, 0.72); (III) a nutritional intervention period ≥6 months cannot significantly improved children's height-for-age z scores; (4) When the nutritional intervention period was <6 months, there was no statistically significant difference in the weight-for-age z scores between the nutritional intervention group and the control group (MD =–0.20, 95% CI: –0.60, 0.20), but when the nutritional intervention period was ≥6 months, the nutritional interventions significantly increased children's weight-for-age (mean difference =2.23, 95% CI: 0.01, 4.44).

Conclusions: Different nutritional interventions had a slight improvement effect on children's physical growth and development. However, the effect of the short-term nutritional interventions (<6 months) was not obvious. In clinical practice, it is recommended that nutritional intervention programs be formulated that can be implemented for longer periods. However, due to the limited literature included, further research is needed.

Keywords: Nutritional intervention; children; growth and development

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Introduction

Child malnutrition is a global problem. It has attracted the attention of policymakers and politicians due to its serious effects on the nation's health and economy (1-4). Malnourished children are more susceptible to infections, which leads to higher morbidity and mortality among children from certain diseases (1,3,5-7). Reasonable dietary nutrition for children is the basis for their healthy growth (8,9). It will directly determine the physical and mental health of children in the future (2). In the long term, it will also affect a country's economic development and overall national strength (2,3,7).

One of the main inducing factors for malnutrition in children is a preference for food, which has a serious impact on their physical development. Therefore, it is necessary to adjust the dietary structure, correct children's unhealthy dietary habits, and fully and adequately consume the necessary nutrients for physical growth. Today, interventions, such as nutrition education and counseling, micronutrient supplementation, food fortification, and macronutrient supplementation, are recommended to improve the nutritional status of children (10-19). Several studies (12,14,16,18,20,21) have assessed the positive effects of nutritional interventions on the physical growth and development of children. However, these studies had a number of limitations, such as being incomplete (e.g., assessing only a single intervention or specific micronutrients), using overlapping age groups, or being conducted for varying lengths of time. Additionally, some of the conclusions reached by different studies have been partly contradictory. Furthermore, dietary habits in different countries and regions may also affect the effectiveness of nutritional interventions. Therefore, overall, the results of this research are highly heterogeneous. Thus, this meta-analysis included randomized controlled trials that adopted different measures for nutritional interventions to comprehensively evaluate the effects of nutritional interventions on children's physical development, thereby further emphasizing the impact of nutritional intervention on the physical development of preschool children. We present this article in accordance with the PRISMA reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-23-205/rc) (22).

Highlight box

Key findings

- Long-term nutritional intervention programs had a more obvious effect on children's physical growth and development than short-term nutritional intervention programs of <6 months.

What is known and what is new?

- Interventions, such as nutrition education and counseling, micronutrient supplementation, food fortification, and macronutrient supplementation, are recommended to improve the nutritional status of children.
- This meta-analysis examined data from randomized controlled trials of different nutritional interventions to evaluate the effects of nutritional interventions on children's physical development.

What is the implication, and what should change now?

- Regardless of the intervention method used, long-term nutritional interventions and educational programs significantly improved the physical development of children. In clinical practice, it is recommended nutritional intervention programs be formulated that can be implemented for longer periods.

Methods

Literature search strategy

A search was conducted to retrieve English- and Chinese-language articles from the PubMed, Embase, Cochrane Library, Wanfang and China National Knowledge Infrastructure (CNKI) databases, and the retrieval was updated to December 28, 2022. The literature search mainly used a combination of subject terms in Chinese or English included: ("nutrition" OR "supplement") AND ("development" OR "physical development") AND ("child" OR "children" OR "pediatrics"). In addition to the original database search, this study also conducted a thorough examination of the citation indexes and reference lists of the retrieved articles to identify any potentially relevant studies that were not initially included.

Inclusion and exclusion criteria

Inclusion criteria

To be eligible for inclusion in this meta-analysis, the articles had to meet the following inclusion criteria: (I) type of study design: report on an original study that adopted a randomized controlled trial design for which the full text was available; (II) population: comprise participants who were children aged <8 years; (III) intervention and Comparison:: include an "intervention group" in which the children received nutritional guidance or nutritional supplementation and a "control group" in which the children, who were similar in age and physical development to those in the intervention group, did not receive nutritional guidance or nutritional supplementation; (IV) outcome: examine the following outcomes, body mass index (BMI)-for-age z score, relative weight-for-height (length) (weight-for-height) z score, height-for-age (length) (height-for-age) z score, and weight-for-age z score; and (V) data: has no missing data.

Exclusion criteria

Articles were excluded from the meta-analysis if they met any of the following exclusion criteria (I) was a duplicate article or the full text of the article was not available; (II) reported on a research experiment that did not adopt a non-randomized controlled trial design; (III) were missing or contained errors that could not be completed or corrected; (IV) did not have the necessary outcome indicators required for this study; (V) comprised a letter, case report, comment, practical guidelines, etc.; (VI) the included objects included children with other underlying diseases; and/or (VII) the article related to an animal experiment.

Outcome observation indicators

The outcome observation indicators included BMI-for-age, weight-for-height, height-for-age, and weight-for-age.

Data extraction

The following data were collected: article title, first author, year of publication, country where the study was conducted, type of study design, sample size of the study, sample age, specific intervention and grouping, age of the control, age of the experimental groups, BMI-for-age z score, weight-for-height z score, height-for-age z score, and weight-for-age z score.

Quality evaluation

Two independent researchers assessed the quality of the articles using the Cochrane Risk of Bias Assessment Tool in Review Manager 5.4. (RevMan, Copenhagen: The Nordic Cochrane Center, The Cochrane Collaboration, 2020.). When the opinions of the researchers differed, the researchers discussed the issue with a third party until a consensus was reached. The Cochrane risk bias assessment evaluated the bias risk from a total of 7 items in 6 aspects. Then, based on the bias risk assessment criteria, the results of "low risk of bias", "high risk of bias", and "unclear risk of bias" were determined for each item.

Statistical analysis

Statistical analysis was performed using Stata/SE 16.0 software (StataCorp., Lakeway Dr, College Station, TX 77845, USA). The basic growth and development index data of children in the "nutritional intervention experimental group" and "control group" were analyzed and compared. The data mainly included BMI-for-age z score, weight-for-height z score, height-for-age z score, and weight-for-age z score. This study utilized continuous variables as outcome indicators, which were presented as mean values with corresponding 95% confidence intervals (CIs). Heterogeneity among the included studies was assessed using the Q test. If the I^2 statistic was less than 50% and P value greater than 0.1, it indicated a low level of heterogeneity, and a fixed-effects model was employed. If not, a random-effects model was used to calculate the combined effect size. The statistical findings of the meta-analysis were displayed using forest plots, and publication bias was evaluated using funnel plots.

Results

Literature search and screening results

The retrieval method described above yielded a total of 429 studies from five databases. After removing duplicate articles, 380 original studies were screened based on their titles, keywords, and abstracts, resulting in 27 potentially relevant articles. Further searches led to obtaining the full text of 24 of these articles, of which 16 studies were excluded from the meta-analysis based on the inclusion and exclusion criteria. Ultimately, 8 studies (23-30) were included in the meta-analysis. The literature screening process is illustrated in *Figure 1*.

Basic characteristics of the included studies

All 8 articles (23-30) included in the meta-analysis reported on original studies, and together, they included a total sample of 6,645 children under the age of 8. The basic characteristics of these studies are outlined in *Table 1*.

Quality assessment of the included articles

Each article's quality was assessed using the Cochrane Risk

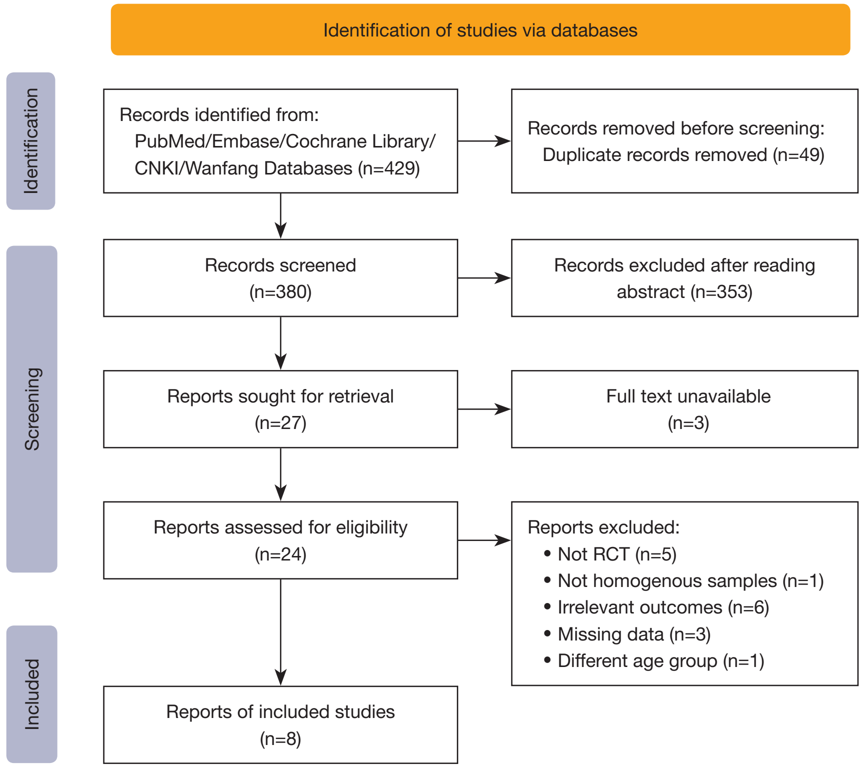

Figure 1 Flow chart of the document screening process. RCT, randomized controlled trial.

of Bias Assessment Tool. The quality assessment results of the included articles are depicted in *Figures 2,3*.

The results and sensitivity analysis of the meta-analysis

Nutritional intervention for children's BMI-for-age improvement

Since the heterogeneity test results for the included studies were I^2<0.001%, a fixed-effects model was utilized for the meta-analysis. The findings revealed no significant difference in BMI-for-age z scores between the nutritional intervention and control groups (mean difference =0.12, 95% CI: −0.07, 0.30, *Figure 4*). Thus, the nutritional interventions did not significantly improve the BMI-for-age z scores in children.

Nutritional interventions for children's weight-for-height improvement

As the heterogeneity test results for the included studies was I^2=99.01%, P<0.001, a random-effects model was used for the meta-analysis. The results showed that there was no significant difference in the weight-for-height z scores between the nutritional intervention group and the control group (mean difference =0.47, 95% CI: −0.07, 1.00, *Figure 5*). Thus, the nutritional interventions did not significantly increase children's weight-for-height z scores. The sensitivity analysis indicated that removing individual studies did not substantially alter the overall effect size, demonstrating that the findings were relatively robust and stable.

Nutritional interventions are long-term processes that affect the body. Thus, this study examined the data for the following two subgroups: (I) subgroup 1, which had an intervention period <6 months; and (II) subgroup 2, which had an intervention period ≥6 months. We analyzed whether the nutritional interventions improved the children's weight-for-height z scores in the subgroups. The results showed that when the nutritional intervention period was <6 months, there was no significant difference in the weight-for-height z scores between the nutritional intervention group and the control group (mean difference =0.66, 95% CI: −0.74, 2.06). However, when the intervention period was ≥6 months, the nutritional intervention significantly improved the children's weight-for-height z scores (mean difference =0.36, 95% CI: 0.00, 0.72, *Figure 6*).

Table 1 Basic characteristics of the included studies

Study (year)	Country	Type of study	Intervention	Duration	Sample size	Age
Annan 2021 (23)	Ghana	A longitudinal school-based intervention study	4 groups: nutrition education, physical activity education, both interventions, or control	6 m	433	4–8 y
Fahmida 2022 (24)	Indonesia	A community-based cluster-randomized controlled trial	Mothers of 6–49-month-old children in the intervention group (n=240) attended parenting classes (twice weekly) and received shredded fish/liver/anchovy and optimized complementary feeding/food-based recommendations	6 m	480	10–42 m
Iannotti 2014 (25)	Haiti	A randomized controlled trial with a parallel design	3 groups: (I) control; (II) 3-m LNS; or (III) 6-m LNS. The LNS provided 108 kcal and other nutrients, including vitamin A, vitamin B-12, iron, and zinc at $80% of the recommended amounts	3/6 m	589	6–11 m
Khanna 2021 (28)	India	A multi-center, prospective, randomized, double-blinded study	Oral nutritional supplements and dietary counseling	3 m	321	24–48 m
Lima 2007 (29)	USA	A prospective double-blinded, randomized, placebo-controlled trial (phase III)	Diet supplemented with alanyl-glutamine	3 m	178	6 m–8 y
Miller 2020 (26)	USA	A longitudinal community-based randomized trial	3 groups: (I) multisectoral community development activities (full package); (II) nutrition education and livestock management training alone (partial package); (III) no intervention (control)	36 m	1,333	6–60 m
Passarelli 2020 (27)	USA	A cluster-randomized trial	2 groups: (I) chicken production intervention (ACGG); and (II) the ACGG intervention with nutrition-sensitive behavior change communication (ACGG + Agriculture to Nutrition), on child nutrition and health outcomes and hypothesized intermediaries	18 m	829	0–36 m
Taneja 2010 (30)	Norway	A double-blind, randomized, placebo-controlled trial	Children received a placebo or zinc supplement daily (10 mg elemental zinc to infants and 20 mg to older children)	4 m	2,482	6–30 m

m, month; y, year; LNS, lipid-based nutrient supplements; ACGG, African Chicken Genetic Gains.

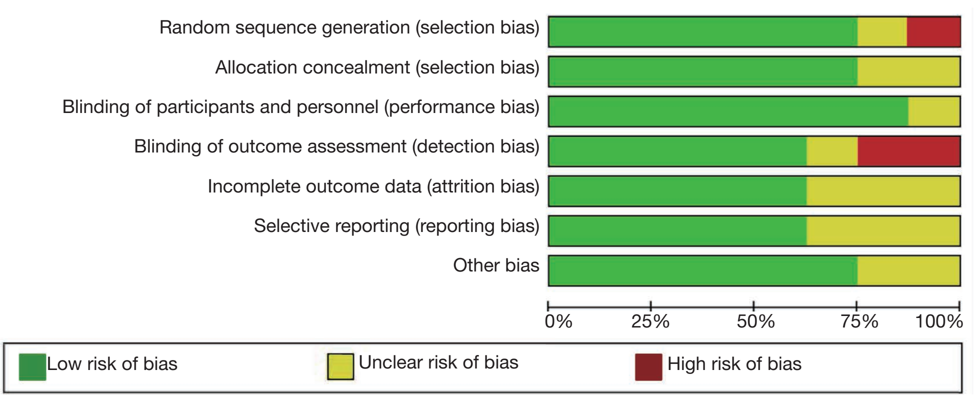

Figure 2 Quality assessment of the included studies.

Nutritional interventions for children's height-for-age improvement

Due to a high degree of heterogeneity among the included studies (I^2=99.96%, P<0.001), a random-effects model was

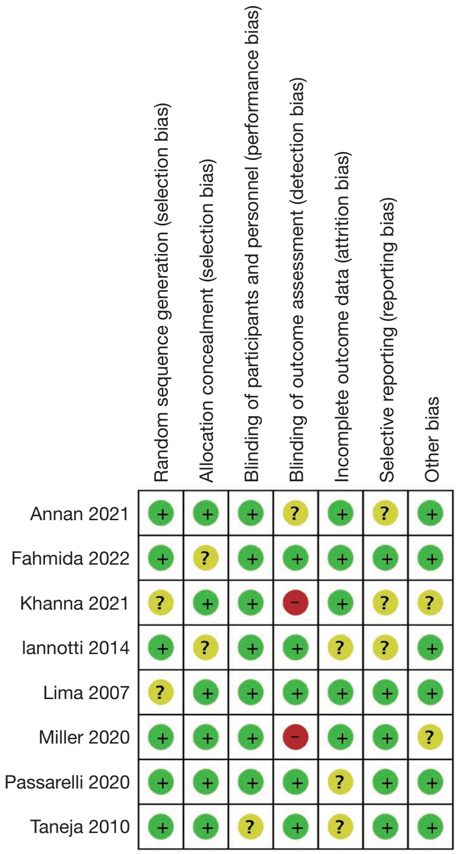

Figure 3 Quality assessment of the included studies. Low risk of bias (represented by green "+"), high risk of bias (represented by red "–"), and unclear risk of bias (represented by yellow "?").

employed for the meta-analysis. The results indicated that there was no significant difference in the weight-for-height z scores between the nutritional intervention group and the control group (mean difference =2.45, 95% CI: –0.79, 5.70, *Figure 7*). Thus, the nutritional interventions did not significantly improve children's weight-for-height z scores. The sensitivity analysis indicated that the overall effect size remained stable, and removing individual studies did not result in significant changes to the results, suggesting the findings were robust.

We also analyzed the effects of the nutritional interventions on the children's height-for-age z scores in the subgroups. The results showed that there was no significant difference in the height-for-age z scores between the nutritional intervention group and the control group when the nutritional intervention period was <6 months (mean difference =0.70, 95% CI: –0.68, 2.07) or when the intervention period was ≥6 months (mean difference =3.61, 95% CI: –1.71, 8.93, *Figure 8*).

Nutritional interventions for children's weight-for-age improvement

Due to a high degree of heterogeneity among the included studies (I^2=99.85%, P<0.001), a random-effects model was employed for the meta-analysis. The findings indicated that there was no statistically significant difference in weight-for-age z scores between the nutritional intervention and control groups. (mean difference =1.24, 95% CI: –0.27, 2.75, *Figure 9*). Thus, the nutritional interventions did not significantly increase the weight-for-age z scores in the children. The sensitivity analysis revealed that removing individual studies did not significantly alter the overall effect size, indicating that the results were relatively stable and robust.

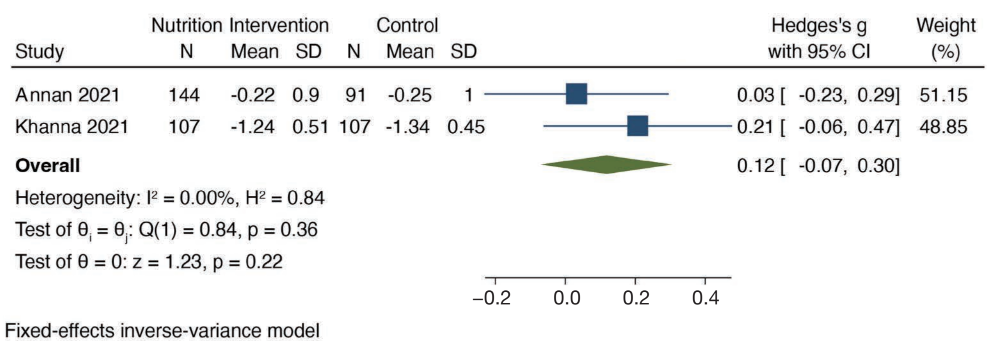

Figure 4 Forest plot of the nutritional interventions for children's BMI-for-age improvement. SD, standard deviation; CI, confidence interval; BMI, body mass index.

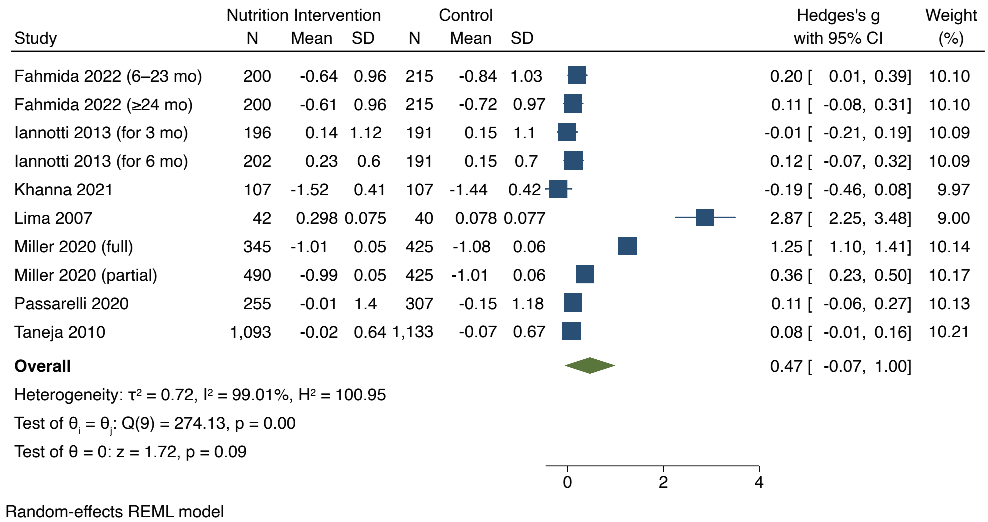

Figure 5 Forest plot of the nutritional interventions for children's weight-for-height improvement. SD, standard deviation; CI, confidence interval; REML, Restricted Maximum Likelihood.

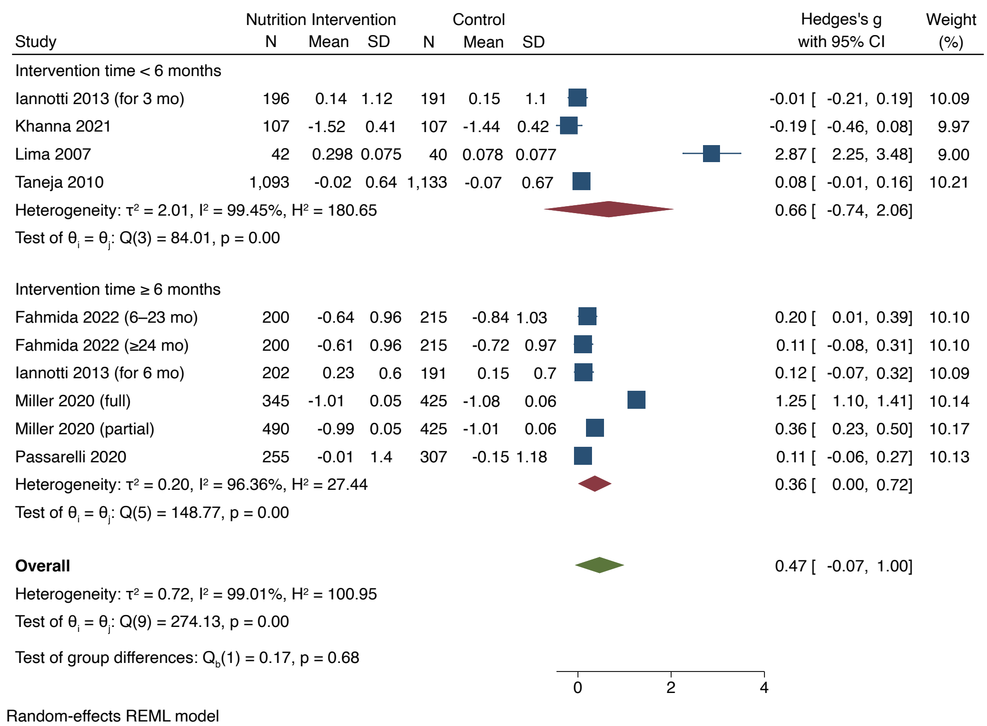

Figure 6 Forest plot of the subgroup analysis of the nutritional interventions for children's weight-for-height improvement. SD, standard deviation; CI, confidence interval; REML, Restricted Maximum Likelihood.

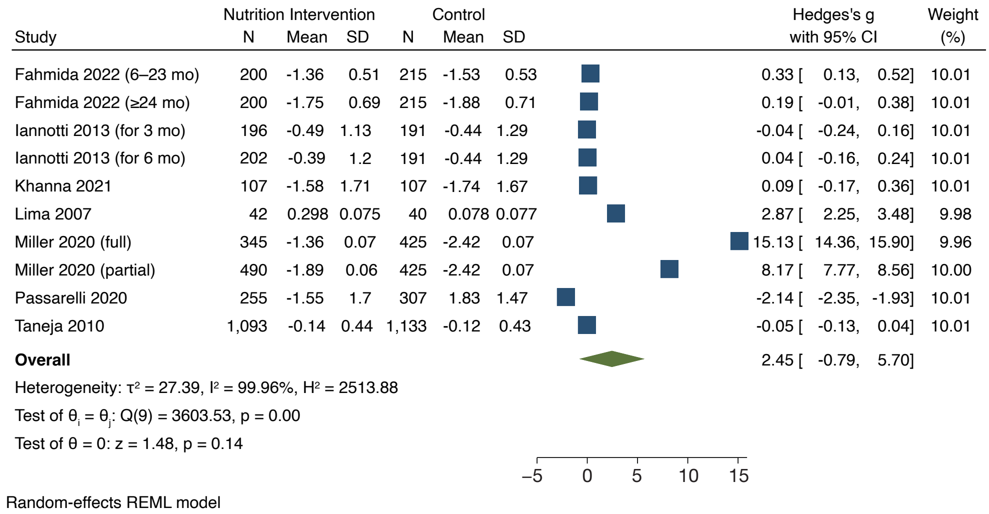

Figure 7 Forest plot of the nutritional interventions for children's weight-for-height improvement. SD, standard deviation; CI, confidence interval; REML, Restricted Maximum Likelihood.

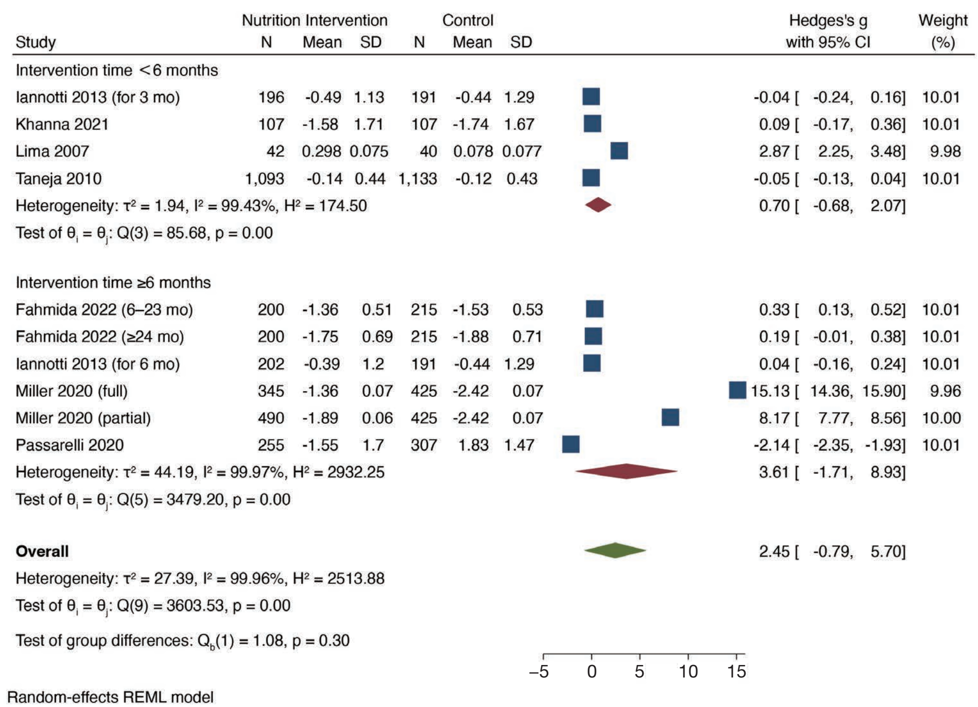

Figure 8 Forest plot of the subgroup analysis of the nutritional interventions for children's height-for-age improvement. SD, standard deviation; CI, confidence interval; REML, Restricted Maximum Likelihood.

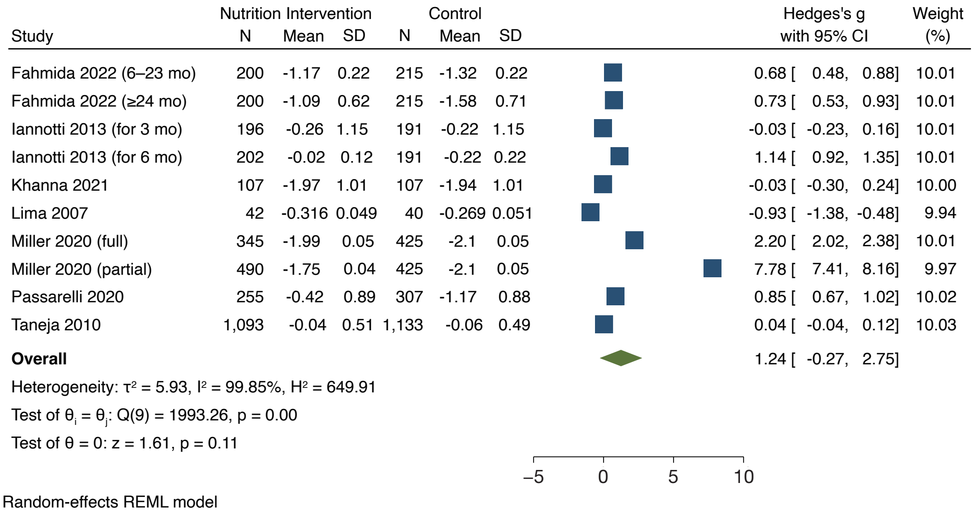

Figure 9 Forest plot of the nutritional interventions for children's weight-for-age improvement. SD, standard deviation; CI, confidence interval; REML, Restricted Maximum Likelihood.

We also analyzed the effects of the nutritional interventions on the children's weight-for-age z scores in the subgroups. The results showed that when the nutritional intervention period was <6 months, there was no significant difference in the weight-for-age z scores between the nutritional intervention group and the control group (mean difference =–0.20, 95% CI: –0.60, 0.20). However, when the intervention period was ≥6 months, the nutritional interventions significantly improved the children's weight-for-age z scores (mean difference =2.23, 95% CI: 0.01, 4.44, *Figure 10*).

Publication bias

The funnel plot indicated a slight asymmetry (*Figures 11-13*), suggesting the possibility of publication bias. However, it was challenging to quantify the extent of the bias.

Discussion

Nutrition plays a crucial role in the transition from adolescence to healthy adulthood (3,7,8). Malnutrition in children and adolescents is associated with delayed development, impaired cognitive maturation, a lower intelligence quotient, behavioral problems, and an increased risk of infectious diseases (3-5,7,9). The World Health Organization classifies a child as stunted if their growth standard median weight or height (length) is less than twice the standard deviation of their peers (9). A child's growth and development affects their ability to learn and be productive (2,4,9,31).

The childhood stage is a critical period for human growth and development (6). The growth and development of children in this stage are easily affected by external factors. In addition, in early childhood, children have relatively weak disease resistance and high nutritional needs, and display fast growth and development (3,32). Thus, it is necessary to implement appropriate health care intervention measures based on the growth characteristics of children in early childhood to promote their growth and development, and effectively avoid the occurrence of various diseases. With the popularization of health knowledge and the deepening of research on children's growth and development, more and more attention has been paid to nutrition educational and intervention programs for children. The question of how to provide children with more systematic and scientific nutrition and educational programs is an important research topic at present. This study focused on children's growth and development to explore the effect of children's nutritional interventions on their physical growth and development.

Several studies (11,13,14,16,17,19-21,33,34) have assessed the positive effects of nutritional interventions on the physical growth and development of children. However, these studies have used different interventions, included overlapping age groups, run for varying lengths of time, and drawn conflicting conclusions. A previous study explored the effects of nutrition education interventions on growth

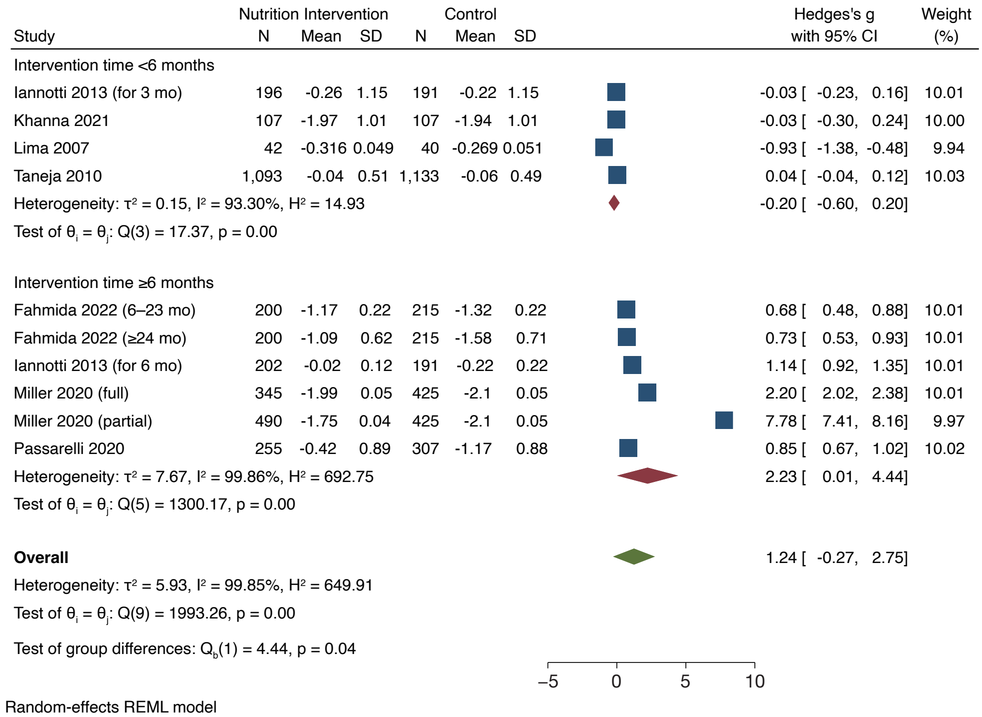

Figure 10 Forest plot of the subgroup analysis of the nutritional interventions for children's weight-for-age improvement. SD, standard deviation; CI, confidence interval; REML, Restricted Maximum Likelihood.

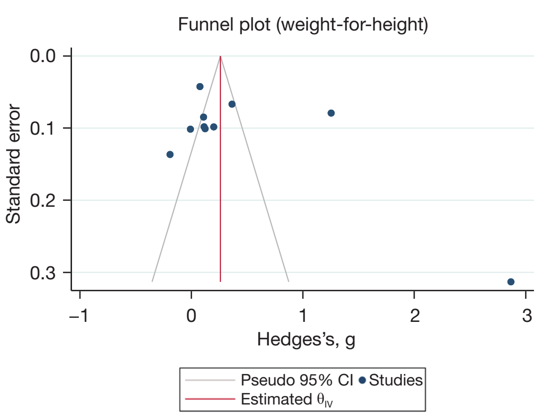

Figure 11 Funnel plot (weight-for-height). CI, confidence interval.

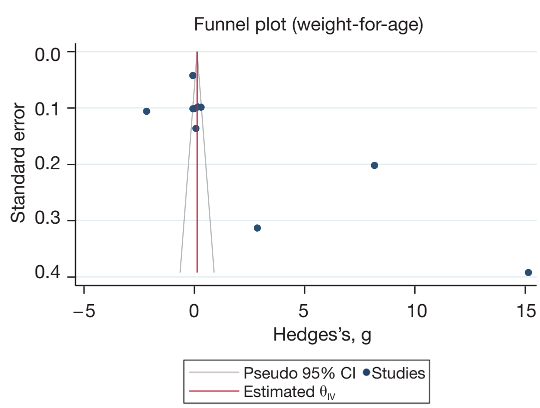

Figure 12 Funnel plot (height-for-age). CI, confidence interval.

and development in food-secure and food-insecure settings, and found that some growth parameters (e.g., height and weight gain) were significantly improved in the food-secure population, but stunting was not improved (35). In the food-insecure population, nutrition education was associated with improved weight-for-age, and weight-for age z scores for height (length) (35). Thus, this meta-analysis included randomized controlled trials that adopted different measures for nutritional interventions to comprehensively evaluate the effectiveness of nutritional interventions on children's physical development. This study also explored the different effects of the time of nutritional interventions on the promotion of children's physical development to provide a theoretical basis for the specific implementation of nutritional intervention programs in clinical practice.

The results of this study showed that there was no

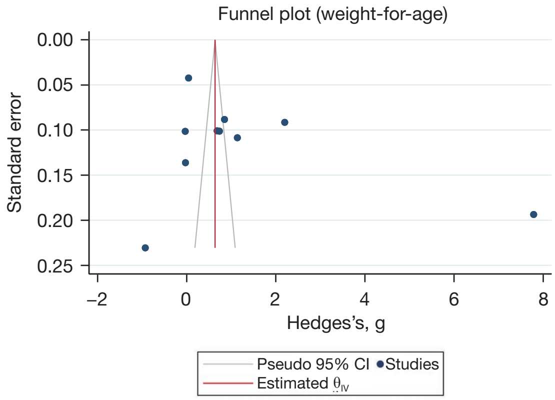

Figure 13 Funnel plot (weight-for-age). CI, confidence interval.

statistically significant difference in the BMI-for-age z scores between the nutritional intervention group and the control group (mean difference =0.12, 95% CI: –0.07, 0.30). Thus, we found that the nutritional interventions did not significantly improve the BMI-for-age z score. When the nutritional intervention period was <6 months, there was no significant difference in the weight-for-height z scores between the nutritional intervention group and the control group (mean difference =0.66, 95% CI: –0.74, 2.06), but when the nutritional intervention period was ≥6 months, the nutritional interventions significantly improved the weight-for-height z scores (mean difference =0.36, 95% CI: 0.00, 0.72). A nutritional intervention period <6 months and an intervention time ≥6 months did not significantly improve the children's height-for-age z scores. When the nutritional intervention period was <6 months, there was no statistically significant difference in the weight-for-age z scores between the nutritional intervention group and the control group (mean difference =–0.20, 95% CI: –0.60, 0.20); however, when the nutritional intervention period was ≥6 months, the nutritional interventions significantly increased children's weight-for-age z scores (mean difference =2.23, 95% CI: 0.01, 4.44).

Dietary diversity has a crucial interaction with children's health status and is an important protective determinant of malnutrition. Malnutrition manifests as chronic and long-term malnutrition with delayed development. Emaciation is a severe form of malnutrition, as well as a combination of stunted growth and emaciation in children. In this regard, a diversified diet after the sixth month is crucial as exclusive breastfeeding is no longer sufficient to meet the nutritional needs of growing children. Another study also confirmed that insufficient intake of dietary diversity has a direct impact on children's growth outcomes, manifested as weight loss and underweight, as well as corresponding severe forms (36). Children who consume sufficient animal derived foods (such as dairy products, meat, and eggs) are least likely to experience developmental delays, weight loss, and underweight. However, there are still some limitations in this study. Only two literatures have used nutritional intervention for more than 6 months, so there may be some meta-analysis results that deviate from the actual situation in long-term nutritional intervention (>6 months) studies.

Conclusions

In conclusion, nutritional interventions are long-term processes that require persistence. The short-term nutritional interventions (<6 months) did not effectively promote children's physical growth and development. However, regardless of the specific intervention method used, the long-term nutritional and educational interventions significantly improved children's physical fitness growth and development, and increased the children's weight-for-height and weight-for-age z scores.

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Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-23-205/rc

Peer Review File: Available at https://tp.amegroups.com/article/view/10.21037/tp-23-205/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-23-205/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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