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REVIEW

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Prevalence of undernutrition and associated factors among children with congenital heart disease in Africa: a systemic review and meta-analysis

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Abstract

Background Undernutrition is a major public health issue in children with congenital heart disease in Africa. In this continent, the degree of undernutrition also varies from country to country. Therefore, summarizing data concerning undernutrition in children with congenital heart disease is essential to refine treatment guidelines and policies. This meta-analysis aims to deliver pooled data concerning undernutrition among African children with congenital heart disease.

Methods In this review, relevant studies were searched via PubMed/MEDLINE online, Science Direct, Hinari, Web of Science, CINHAL, EMBASE, WHO database, Google, and Google Scholar. To conduct this review, PRISMA guidelines were used. STATA 17 was used to estimate the pooled prevalence of undernutrition in children. A random effect meta-analysis model was used to conduct this meta-analysis. The heterogeneity of the studies was evaluated by the I2 test. Publication bias was assessed via funnel plots supplemented with Egger's weighted regression test. Finally, for all analyses, $p < 0.05$ was considered statistically significant.

Result In this review, a total of 5898 studies were found. Among these, 5878 were excluded using PRISMA, and the remaining 20 studies were included in the final analysis. The prevalence of undernutrition, underweight, wasting, and stunting in children with congenital heart disease was 65.14% (95% CI 51.32–78.95, $I^2 = 97.4\%$, $p = 0.0001$), 45.76% (95% CI 35.83–55.69, $I^2 = 96.7$, $p < 0.0001$), 39.37% (95% CI 29.55–49.19, $I^2 = 97.4$, $p < 0.0001$), and 39.38% (95% CI 33.02–45.72, $I^2 = 92.4\%$, $p < 0.0001$), respectively. Anemia (OR = 4.5, 95% CI 1.60–12.68), CHF (OR = 5.98, 95% CI 3.09–11.57), pulmonary hypertension (OR = 2.76, 95% CI 1.89–4.04), and age (OR = 2.78, 95% CI 1.79–4.31) were associated with undernutrition in children with CHD.

Conclusion In this meta-analysis, the pooled prevalence of undernutrition and its indicators in children with CHD were high. As a result, there is still a need to improve early screening and treatment of undernutrition in children with congenital heart disease concomitant with early screening and treatment of congenital heart disease and its common complications in Africa.

Keywords Undernutrition, Congenital heart disease, Children, Africa

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Introduction

Undernutrition is a prevalent problem in the pediatric population in Africa. It usually occurs due to an improper diet or a poor socioeconomic background. However, it is important to note that undernutrition may result from medical conditions. As many studies have shown, congenital heart disease (CHD) is one of the leading causes of childhood malnutrition [1].

CHD is one of the most common congenital birth abnormalities with a high mortality rate [2]. Even though CHD is a global problem, children in low- and middle-income countries have disproportionally high rates of mortality and morbidity as compared to industrialized countries. Every year, ~ 500,000 children are born with CHD in Africa [3]. For instance, from children with cardiac disease (acquired and congenital) in Nigeria, 34.4%, 15.9%, and 11.6% of children had ventricular septal defects (VSD), patent ductus arteriosus (PDA), and tetralogy of Fallot (TOF), respectively [4]. In addition, in Tanzania, from a total of CHD children, 19.3% of children had VSD, 19.1% had patent duct PDA, 15.1% had ASD, and 4.6% had atrioventricular septal defect (AVSD). Furthermore, around 35% had cyanotic CHD, 13.3% TOF, followed by double outlet right ventricle (DORV) (3.6%) [5] from children with CHD. Approximately one-third of children with CHD require interventions such as open surgery, catheterization, and pharmacologic treatment. Because of the inadequacy of those interventions, those children are exposed to malnutrition [6]. Most children with CHD have a normal birth weight at birth. Even though they had a normal birth weight, those children develop nutritional and growth problems gradually, especially in the first month of life [6, 7]. According to the WHO and UNICEF joint report, 12.6% of children without CHD were underweight, 6.7% were wasted, and 22% were stunted [8]. However, the prevalence of malnutrition in children with CHD ranges from 15 to 64% globally [9]. The pooled prevalence of underweight, wasting, and stunting worldwide is 27.4%, 24.84%, and 24.4%, respectively, among CHD children [10]. In Europe, 28–54%, 22–51%, and 16–64% of children with CHD are underweight, stunted, and wasted, respectively. In addition, a study in Iran reported that 60.9% of children with CHD were wasting, whereas 61.8% were stunted [11]. In addition, recent DHS data in Africa showed that 34.7%, 14.8%, and 5.1% of children without CHD were stunted, underweight, and wasted, respectively [12]. However, as studies have consistently shown in Africa, 52–92% of children with CHD develop undernutrition [13–17]. This showed that children with CHD were high risk for undernutrition as compared to children without CHD. Moreover, the prevalence of undernutrition among children with CHD varies according to the population studied. According to Okoromah and colleagues, a study done in Nigeria reported a prevalence of undernutrition and severe undernutrition in children with CHD were (90.4%) and (61.2%), respectively. In addition, the prevalence of wasting in a cyanotic CHD was 58.3% and the prevalence of stunting in children with cyanotic CHD was 68.0% [18]. Multiple heart defects, heart failure, delayed intervention, anemia, and pulmonary hypertension increase the development of undernutrition in children with CHD [19]. This implies that the magnitude of undernutrition in children with CHD varies from one country to another, the populations studied, and its risk factors. Despite the presence of variation in the magnitude of undernutrition in children with CHD in Africa, there were no regionally representative pooled data on the prevalence of undernutrition and associated factors in children with CHD. Therefore, reliable and summarized information about undernutrition and associated factors in children with CHD is essential for refining government policies, strategies, and interventions in Africa. Thus, this systematic review and meta-analysis aimed to estimate the pooled prevalence of undernutrition and associated factors among children with CHD in Africa. As a result, the findings of this review and meta-analysis play a significant role in providing summarized evidence and suggesting possible applicable strategies for planning, decision-making, and resource allocation in the African healthcare system.

Materials and methods

Study identification

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards. To determine the final number of studies included in this meta-analysis, studies were searched using various search strategies. The published and unpublished studies on the prevalence of undernutrition, stunting, wasting, and underweight and associated factors among children with congenital heart disease in Africa were reviewed. During the reviewing process, duplicate studies were checked and removed. After removing duplicated studies, irrelevant studies were excluded based on title and abstract. Then full-text articles were assessed for eligibility, and full-text articles that met all eligibility criteria were included in the final analysis.

Eligibility criteria

This review included observational studies (cross-sectional, cohort, and case–control) that assessed the prevalence of undernutrition, wasting, underweight, and stunting among children aged 0–18 years with congenital heart disease in Africa. This analysis excluded studies that did not report the prevalence of undernutrition or one or more undernutrition indicators (stunting, underweight, or wasting). Furthermore, in this review, we did not include case report, qualitative research, experimental investigations, systematic reviews, and review articles.

Outcomes of measurement

The outcome of this systematic review and meta-analysis is the pooled prevalence of undernutrition, underweight, wasting, and stunting and associated factors among children with congenital heart disease in Africa. Studies used the WHO criteria to screen for stunting, underweight, and wasting using the height for age-Z score (HAZ), weight for age-Z score (WAZ), and weight for height-Z score (WHZ), respectively were included in this review. The prevalence was measured as the percentage of undernutrition, stunting, underweight, and wasting among children with congenital heart disease.

WHO z-score criteria for underweight, wasting and stunting

Stunting—height-for-age < -2 SD of the WHO Child growth standards median;

Wasting—weight-for-height < -2 SD of the WHO Child growth standards median.

Underweight—weight-for-age < -2 standard deviations (SD) of the WHO Child growth standards median.

Source of information and search strategy

This study estimated the pooled prevalence of undernutrition, underweight, wasting, stunting, and their associated factors in Ethiopia. We checked the DARE (database of abstracts of reviews of effects) (http://www.library.UCSF.edu) and Cochrane Library to ensure that this had not been done before and to avoid duplication of the work. We also checked the PROSPERO database to ensure that there was an ongoing systemic review and meta-analysis with similar titles. These checked databases reassured us that no previous similar studies had been performed.

Relevant studies were searched via the PubMed/MEDLINE online, Science Direct, Hinari, CINHAL, and WHO databases. In addition, gray literature (Google and Google Scholar) was used to identify the required studies. The key terms prevalence, magnitude, proportion, malnutrition, undernutrition, stunting, underweight, wasting, nutritional status, nutritional assessment, anthropometric measurement, associated factors, determinants, predictors, risk factors, congenital heart disease, congenital heart defects, congenital heart anomalies, children, and Africa were used to retrieve studies. These search terms were predefined to allow comprehensive search strategies that include all important studies. All fields included in the records and medical subject headings (MeSH terms) combined with Boolean operations ("OR", "AND") were used to search the advanced PubMed search engine (Supplementary file 1).

Quality appraisal

The principal investigator (MA), DB, and MS were performing an initial review by title and abstract to eliminate articles that were visibly not important for this review. Full-text articles and abstracts that reported the magnitude or prevalence of undernutrition and one or more indicators of undernutrition (wasting, underweight, or stunting) and/or associated factors were included in this review. Three investigators (DB, KG, and TA) independently screened the selected full-text studies using our eligibility criteria. During the selection process, disagreements among the authors were resolved by mediation of the fourth author (DS) for the final decision to be included in the analysis.

The quality of the studies was assessed via the Newcastle–Ottawa quality assessment scale [20]. The tool has three main parts. The first parts focus on the methodological quality of each original study and are graded out of five stars. The second part assesses the comparability of primary studies with a possibility of a two-star score, and the final part of the tool measures the quality of the original articles in terms of their outcome and statistical analysis with a possibility of a three-star score. Four authors (TE, MG, AM, and MA) independently evaluated the quality and clarity of the methodology, the reported data, and the design of the included studies. Any discrepancy among the four authors during the quality assessment was resolved by discussion. Articles with a score of 7 or higher out of 10 stars were considered to be of high-quality study and included in this meta-analysis.

Study selection and data extraction

The retrieved articles were exported to the reference manager software ZOTERO and used to remove duplicate studies. Four independent reviewers screened the titles and abstracts. Any disagreement was handled on the basis of established article selection criteria. All necessary data were extracted via a standardized data extraction format prepared in Microsoft Excel for undernutrition, stunting, underweight, and wasting.

The extraction methods included the first author's name, publication year, country, sample size, response rate, study design, and prevalence of undernutrition, underweight, stunting, wasting and associated factors.

Data analysis and interpretation

The data extracted from Microsoft Excel were exported to STATA Version 17.0 for analysis. A random effect meta-analysis model was used to conduct this meta-analysis. A forest plot was used to show the pooled estimate of undernutrition with a 95% confidence interval (CI). The heterogeneity of the studies was evaluated by the I^2 test. Publication bias was assessed via funnel plots supplemented with Egger's weighted regression test. Subgroup analysis was performed according to country, study design, and year of publication. Finally, for all analyses, $p < 0.05$ was considered statistically significant.

Results

A total of 5898 publications were found during the initial electronic database search of PubMed (166), Science Direct (2884), Hinari (869), CINHAL (1064), WHO (17), Google (16), and Google Scholar (882) databases. After 2467 duplicates were removed, 3431 records remained. An additional 2882 records were excluded by title, and 325 were excluded by abstract. The full texts of the remaining 224 articles were screened, and an additional 204 articles were excluded by reason (country (outside Africa), (population (adult), and type of studies (systemic review and meta-analysis) were excluded. Finally, 20 records were included in this systematic review and meta-analysis (Fig. 1).

Characteristics of the included articles

In this review, 20 primary research articles with a total of 3156 participants were considered. Seven of these studies

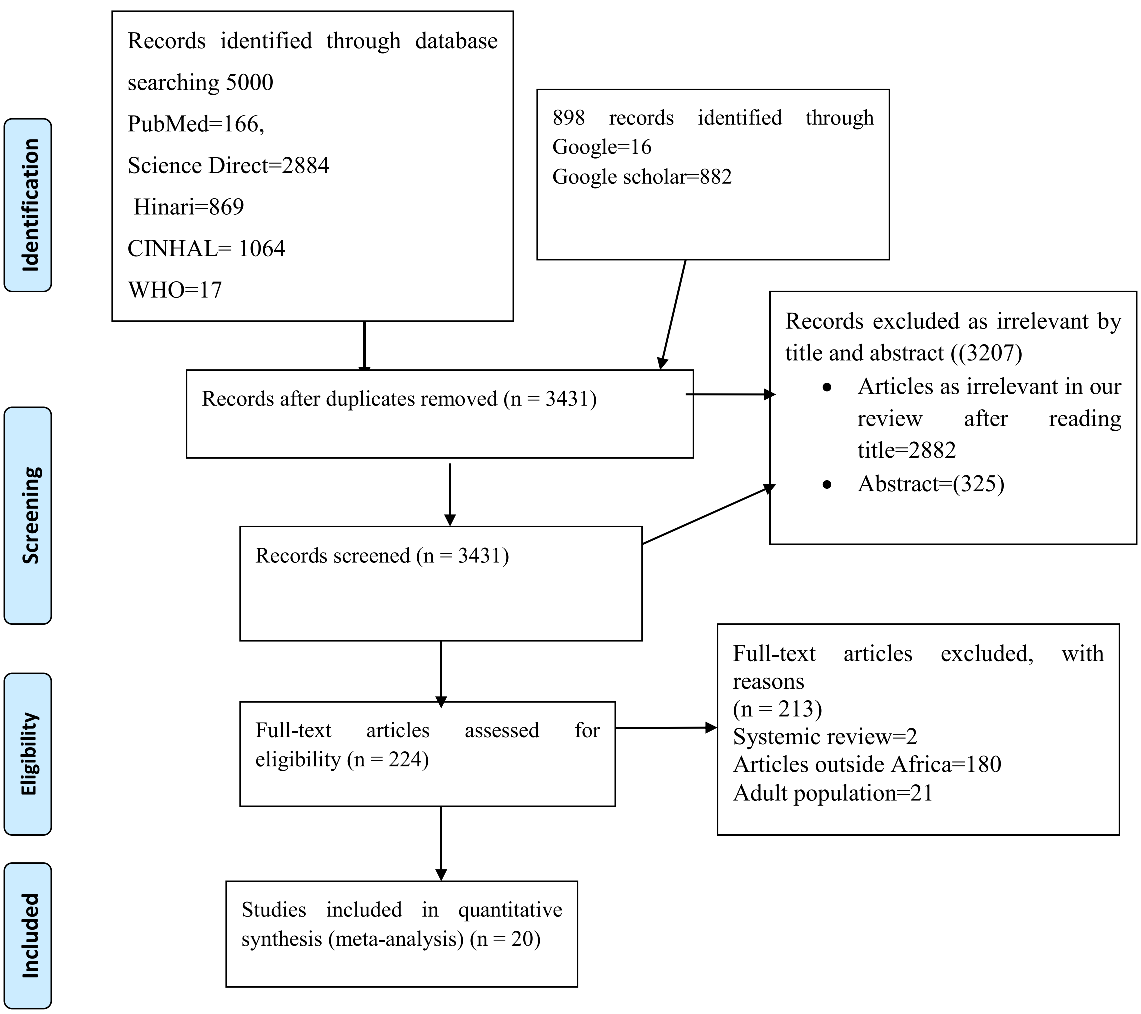

Fig. 1 Flow chart describing the selection of primary studies conducted on under-nutrition among children with congenital heart disease in Africa

Table 1 distribution of included studies on the prevalence of under-nutrition among children with congenital heart disease in Africa, 2024

Authors	Publication year	Countries	Sample size	Response rate (%)	Study design	% under nutrition	% underweight	% wasting	% stunting	Score	References
Hanan et al.	2019	Egypt	100	100	Case control	86	11.6	60.4	27.9	7	[17]
Okoromah et al.	2014	Nigeria	73	100	Case–control	90.4	20.5	41.1	28.8	7	[18]
Batte et al.	2017	Uganda	194	100	Cross-sectional	-	39.6	23.2	45.4	8	[19]
Hassan et al.	2015	Egypt	100	100	Case–control	84	14.3	23.8	61.9	7	[21]
Balogun et al.	2015	Nigeria	293	100	Case–control	-	47	34	37	8	[22]
Tamirat et al.	2017	Ethiopia	293	100	Case–control	-	79	62	52	8	[23]
Isezuo et al.	2017	Nigeria	85	100	Cross-sectional	-	72.9	60.8	57.8	8	[24]
Ogunkunle et al.	2017	Nigeria	151	100	Cross-sectional	72.8	64.2	37.7	57	7	[25]
Shamsa	2022	Kenya	242	100	Cross-sectional	47.9	35.5	25.6	17.4	9	[13]
Robyn	2024	South-Africa	40	100	Prospective observational	-	67.5	22.5	45	8	[26]
Rediet et al.	2021	Ethiopia	373	100	Cross-sectional	-	38.3	38.6	35.9	9	[27]
Temesgen et al.	2022	Ethiopia	228	100	Cross-sectional	-	49.1	43.1	43	9	[28]
Samuel et al.	2022	Gahna	167	100	Retrospective cross-sectional	-	41.5	20.5	21.3	7	[29]
Bruk et al.	2020	Ethiopia	141	100	Retrospective cross-sectional	51.8	49.6	63.1	29.8	9	[30]
Onalo et al.	2021	Nigeria	50	79	Cross-sectional	52	60	72	46	7	[14]
Labib et al.	2019	Egypt	300	100	Cross-sectional	47	44	6.7	29.7	8	[16]
Chinawa et al.	2021	Nigeria	291	100	Comparative cross-sectional	–	–	38.5	37.8	8	[31]
Mulat et al.	2020	Ethiopia	269	100	Cross-sectional	30.5	–	–	–	8	[32]
El-Koofy et al	2017	Egypt	50	100	Cohort	62	–	–	–	7	[33]
Arodiwe et al	2015	Nigeria	50	100	Cross-sectional	92	–	–	–	8	[15]

were conducted in Nigeria, whereas five investigated undernutrition and its indicators (wasting, stunting, and underweight) in Ethiopia. Furthermore, five articles in Egypt and one each in Uganda, Kenya, South Africa, and Ghana assess the problem of undernutrition and its indicators in children with CHD (Table 1).

This review included only observational studies, with sample sizes ranging from 40 to 373 in studies conducted in South Africa and Ethiopia, respectively. These studies employed WHO standards to determine underweight, wasting, and stunting. Seventeen studies reported wasting and stunting, whereas sixteen reported being underweight. In addition, 11 studies reported undernutrition without considering wasting, underweight, and stunting separately. In the extracted records, Nigeria had the highest prevalence of undernutrition, whereas Ethiopia had the lowest prevalence of undernutrition (Table 1).

The prevalence of underweight was highest in Nigeria and lowest in Egypt. Similarly, Nigeria had the highest reported prevalence of wasting, whereas Egypt had the lowest. In addition, Egypt and Kenya presented the highest and lowest magnitudes of stunting, respectively (Table 1).

Meta-analysis

The overall pooled prevalence of undernutrition among 11 articles was 65.14% (95% CI 51.32–78.95, $I^2 = 97.4\%$, $p = 0.0001$) (Fig. 2), whereas out of sixteen articles reporting underweight, the pooled prevalence of underweight was 45.76% (95% CI 35.83–55.69, $I^2 = 96.7\%$, $p < 0.0001$) (Fig. 3). Similarly, the pooled prevalence of wasting was 39.37% (95% CI 29.55–49.19, $I^2 = 97.4\%$, $p < 0.0001$) (Fig. 4). In addition, the pooled prevalence of stunting among 17 articles was 39.38% (95% CI 33.05–45.72, $I^2 = 92.4\%$, $p < 0.0001$) (Fig. 5).

Subgroup analysis

Subgroup analysis by country

The pooled prevalence of undernutrition in children with CHD was highest in Nigeria (77.8% (95% CI 63.38–92.14, $I^2 = 91.9\%$, $p = 0.0001$)) and lowest in Ethiopia (40.9% (95% CI 20.1–61.8, I2 = 94.4, $p = 0.0001$)). Furthermore, the pooled prevalence of underweight among children with congenital heart disease was high in Ethiopia (54.05% (95% CI 33.53–74.57, $I^2 = 98\%$, $p < 0.001$)) and lowest in Egypt (23.46%((CI 1.42- 45.5, $I^2 = 96.6$, $p < 0.0001$)). Moreover, the pooled prevalence of wasting was high in Ethiopia (51.56%, (95% CI 38.8–64.3,

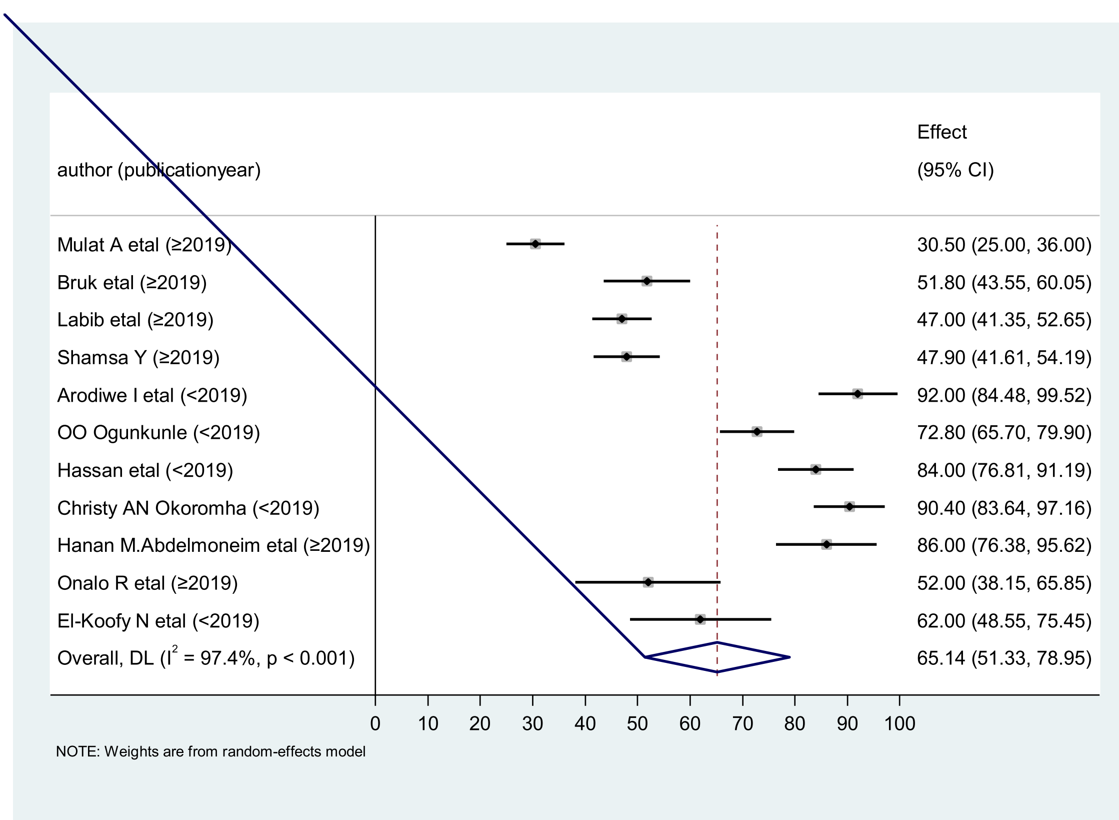

Fig. 2 Forest plot showed the pooled prevalence of undernutrition at a 95% confidence interval

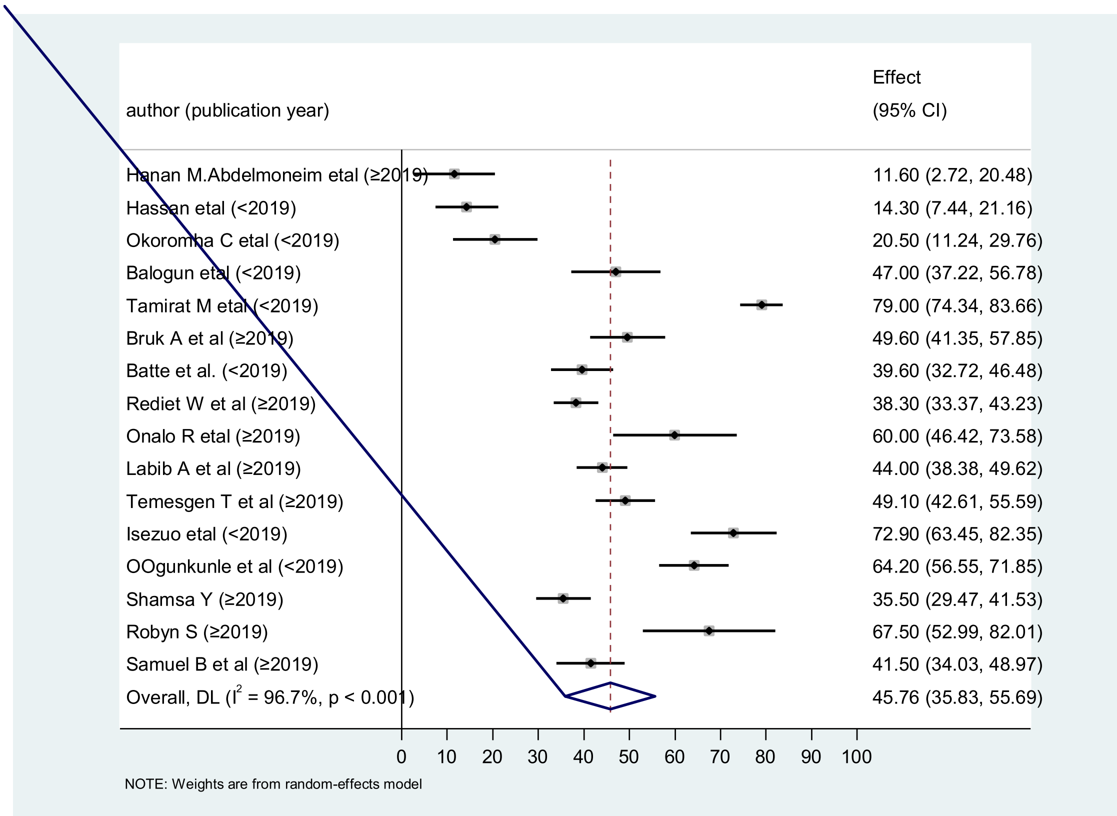

Fig. 3 Forest plot showed the pooled prevalence of underweight at a 95% confidence interval. The diamond shape in the plot presents the pooled prevalence of underweight and the horizontal line in each study showed the confidence interval and the black rectangle on the horizontal line indicates the weight of each study

$I^2 = 94.4\%$, $p < 0.001$)) and lowest in Egypt 29.49% (95% CI 3.81–55.16, $I^2 = 97.1\%$, $p < 0.0001$). Furthermore, the highest pooled prevalence of stunting was in Nigeria (45.44%, 95% CI 33.84–57.03, $I^2 = 84.9\%$, $p < 0.001$), and the lowest was in Egypt (39.85%, 95% CI 18.51–61.18, $I^2 = 94.4\%$, $p < 0.001$) (Table 2).

Subgroup analysis by year of publication

The pooled prevalence of undernutrition in children with CHD in studies published between 2019 and 2024 was 52.2% (95% CI 38.87–65.58, $I^2 = 95\%$, $p < 0.0001$), whereas from 2014 to 2019, it was 81.2% (95% CI 71.88–90.43, $I^2 = 85.4\%$, $p < 0.0001$). Furthermore, the pooled prevalence of underweight among children with congenital heart disease in Africa from studies published between 2019 and 2024 was 43.21% (95% CI 35.52–50.90, $p < 0.0001$), with high heterogeneity ($I^2 = 89.8\%$). However, among papers published between 2014 and 2019, the pooled prevalence of underweight was 48.73% (95% CI 27.72–68.78, $I^2 = 98.2\%$, $p < 0.0001$). From 2014 to 2019, the pooled prevalence of wasting was 40.2% (95% CI 25.1–55.3, $I^2 = 95.9\%$, $p < 0.00001$), whereas from 2020 to 2024, it was 38.9% (26.60–51.24, $I^2 = 97.6\%$, $p < 0.0001$). Furthermore, the pooled prevalence of stunting was 48.7% (95% CI 41.01–56.45, $I^2 = 83.6\%$, $p < 0.00001$) in publications published from 2014 to 2019, whereas in research published from 2020 to 2024, it was 32.58% (26.47–38.68, $I^2 = 87.4\%$, $p < 0.0001$) (Table 2).

Subgroup analysis by study design

In all cross-sectional studies, the pooled prevalence of undernutrition among children with congenital heart disease was 56.3% (95% CI 40.72–71.79, $I^2 = 97.1\%$, $p < 0.0001$). In the case–control studies, it was 87.1% (95% CI 82.72–91.49, $I^2 = 0.00$, $p < 0.431$). On the other hand, the pooled prevalence of underweight in children with congenital heart disease in Africa was 50.23% (95% CI 43.44–57.02, $I^2 = 89.3\%$, $p < 0.0001$) in cross-sectional studies and 34.55% (95% CI 3.06–66.04, $I^2 = 98.9\%$, $p < 0.0001$) in case–control studies. In cross-sectional studies, the pooled prevalence of wasting was 37.4% (95% CI 26.3–48.5, $I^2 = 97.5\%$, $p = 0.507$), whereas in case–control studies, it was 44.16% (27.48–60.85,

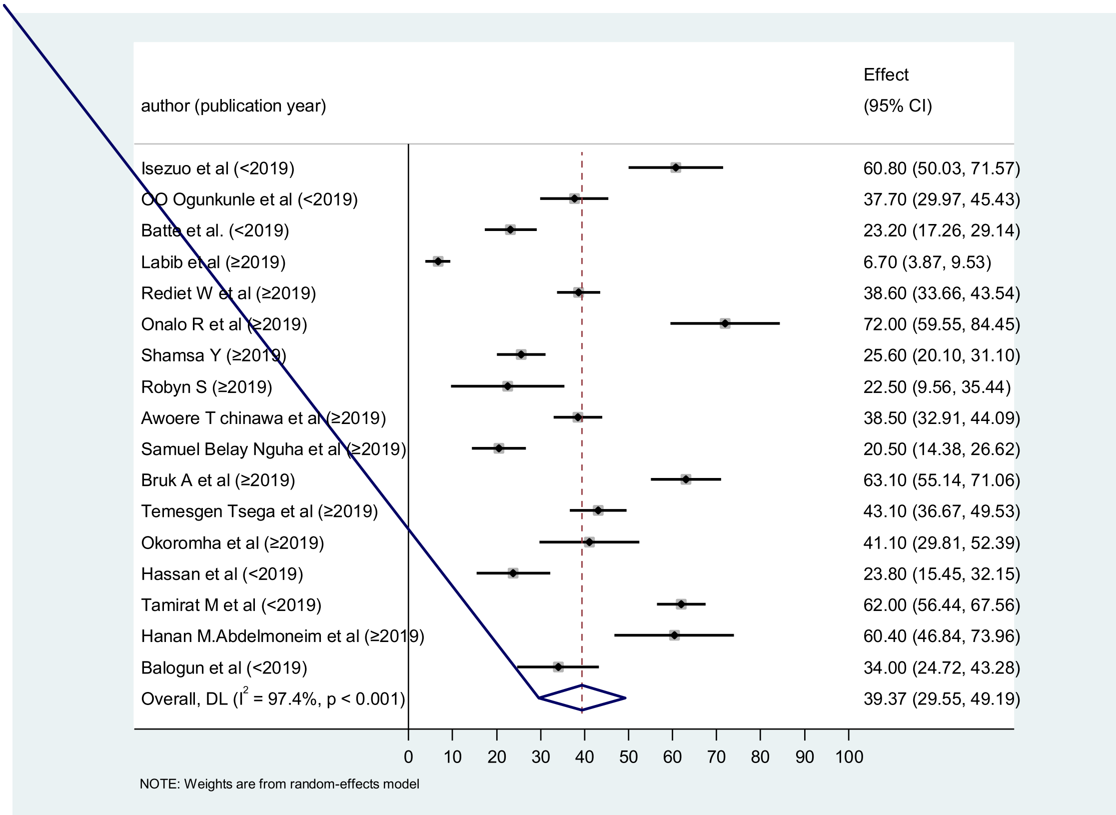

Fig. 4 Forest plot presented a pooled prevalence of wasting at a 95% confidence interval

$I^2 = 94.3\%$, $p < 0.001$). In addition, in cross-sectional studies, the pooled prevalence of stunting was 38.28% (95% CI 31.17–45.38, $I^2 = 92.4\%$, $p < 0.0001$), whereas in case–control studies, it was 41.96% (95% CI 29.61–54.31, $I^2 = 89.2\%$, $p < 0.001$) (Table 2).

Publication bias

A funnel plot is shown in Fig. 6, and Egger's test ($p = 0.316$) for undernutrition revealed no publication bias. Figures 7 and 8 show a funnel plot for underweight and stunted individuals, indicating that there was no publication bias. Furthermore, the Egger test for underweight and stunting demonstrated the absence of publication bias, with $p = 0.623$ and $p = 0.137$, respectively. However, the funnel plot for wasting revealed the existence of publication bias. However, Egger's test revealed no evidence of publication bias ($p = 0.004$) (Fig. 9).

Factors associated with undernutrition

In this review, many variables associated with undernutrition among children with congenital heart disease were identified from primary studies. However, variables significantly associated with undernutrition in at least three primary studies were incorporated into the analysis. Accordingly, age, anemia, pulmonary hypertension, and congestive heart failure were significantly associated with undernutrition in children with CHD.

Age was reported as an associated factor with undernutrition in children with CHD in three primary studies. A total of 464 participants were included in the analysis to determine the association between age and undernutrition in children with CHD. The pooled odds ratio revealed that children aged less than one year were 2.61 times more likely to be undernourished than children aged > 1 year with congenital heart disease (OR = 2.61; 95% CI 1.77–3.86). In addition, three studies with a total of 707 participants reported that anemia was an associated factor for undernutrition in children with CHD. The odds of undernutrition among anemic children with CHD were 4.5 times greater than those among no anemic children with CHD (OR = 4.5 (95% CI 1.6–12.68)). On the other hand, three studies with a sample size of 881 were included in the analysis to determine the association of pulmonary hypertension with undernutrition in children with CHD. The odds of undernutrition among pulmonary hypertensive children with CHD were 2.76 times greater than those among non-pulmonary

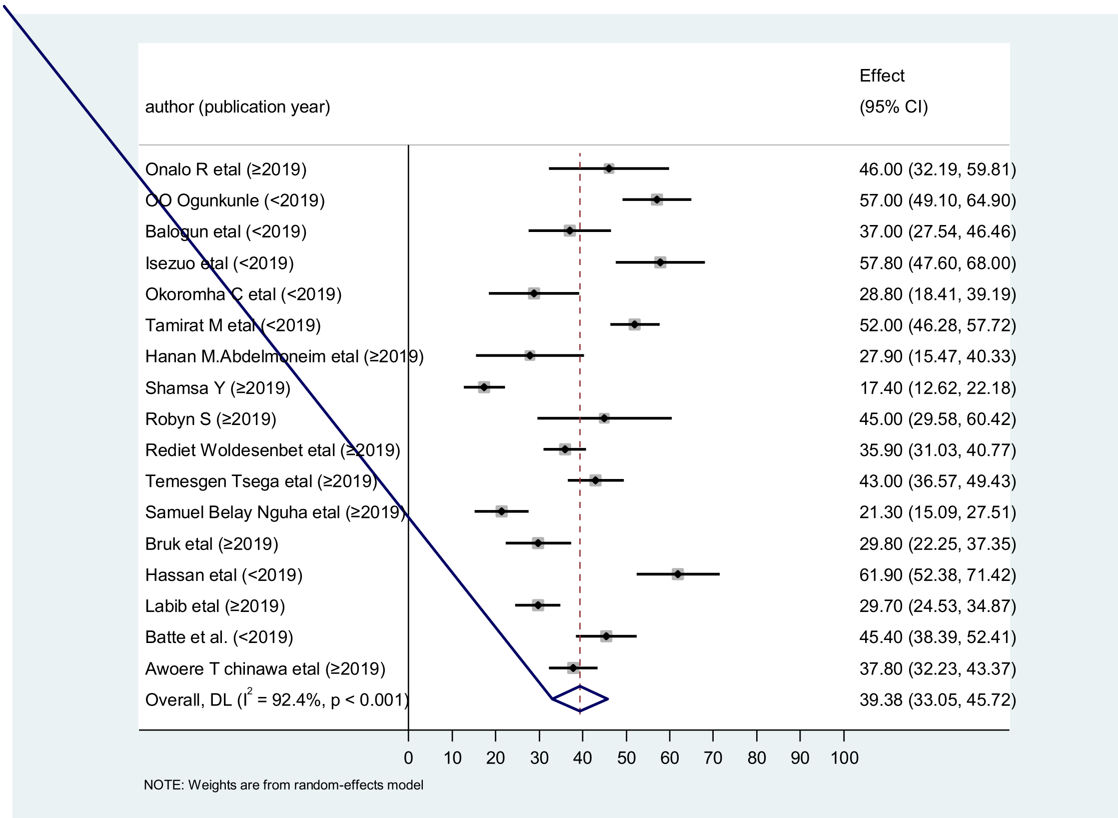

Fig. 5 Forest plot presented a pooled prevalence of stunting at a 95% confidence interval

hypertensive children with CHD (OR = 2.76 (95% CI 1.89–4.04)). Moreover, three primary articles with 759 samples were included in the analysis to determine the associations of congestive heart failure with undernutrition in CHD children. The odds of undernutrition among CHF children with CHD were 5.98 times greater than those among non-congestive heart failure children with CHD (OR = 5.98 (CI 3.09–11.57)) (Table 3).

Discussion

Undernutrition is one of the leading causes of high morbidity and mortality in African children with CHD. This systematic review and meta-analysis revealed the pooled prevalence of undernutrition, underweight, wasting, and stunting among African children with congenital heart disease. According to this review, the pooled prevalence of undernutrition in children with CHD was 66.69%, whereas the pooled prevalence of underweight was 45.76%. This is higher than the findings of studies in China (36.1%), Thailand (28%), and Italy (5.6%) [34–36]. The possible reason might be differences in the economy and accessibility of treatment among the population. In contrast, it is lower than that reported in studies conducted in India (82.5–87.3%), Iraq (60.9%) and Indonesia (49%) [11, 37–39]. The reason for this high variation could be the variation in the magnitude of congenital heart disease in children in each country.

The pooled prevalence of wasting in this review was 39.37%. This finding is significantly greater than those of studies conducted in China (29.7%), Thailand (22%), Italy (7.4%), and Indonesia (31.4%) [29–34] but lower than those of studies conducted in India (72.7%), Indonesia (64%), and Iraq (60.9%) [11, 24]. The likely explanation for this discrepancy could be a difference in parental awareness and knowledge, as children with congenital heart disease are at risk of malnutrition.

This study finding showed that the pooled prevalence of stunting was 39.38%. This finding is higher than those reported in studies conducted in China (21.3%), Thailand (16%), and Italy (6.5%) [34–36]. The possible reason for this discrepancy could be inadequacy of early screening and early treatment of children with CHD in Africa. In contrast, the estimated prevalence reported in this study is lower than that reported in studies from Wardha (58.7%), Maharashtra (43.6%), and Pradesh (53.8%) [25, 26]. This review demonstrated that the pooled prevalence of stunting was lower than that reported in previous studies in Indonesia, such as Bali (51%), Jakarta

Table 2 Summery of sub-group analysis for underweight, wasting and stunting among children with congenital heart disease in Africa, 2024

Type	Feature	Number of studies and participants				Pooled magnitude of undernutrition,	Pooled magnitude of underweight	Pooled magnitude of wasting	Pooled magnitude of stunting
		Undernutrition	Underweight	Wasting	Stunting				
Sub-group analysis by region	Ethiopia	Study (S) = 2 Participants (P) = 410	S = 4 P = 1,035	S = 4 P = 1035	S = 4 P = 1035	40.9% (95% CI 20.1–61.8, $I^2 = 94.4$, p = 0.0001)	54.05% (CI 33.53, 74.57, $I^2 = 98\%$, $p \le 0.001$)	51.56% (CI 38.8–64.3, $I^2 = 94.4\%$, $p < 0.0001$	40.31 (CI 31.23–49.39, $I^2 = 89$, $p \le 0.0001$
	Egypt	S = 4 P = 500	S = 3 P = 450	S = 3 P = 450	S = 3 P = 450	69.73% (95% CI 47.86–91.59, $I^2 = 67$, p = 0.048	23.46 (CI 1.42–45.5, $I^2 = 96.6$, $p < 0.0001$)	29.49 (CI 3.81–55.16, $I^2 = 97.1$, $p < 0.0001$	39.85 (CI 18.51–61.18, $I^2 = 94.4$, $p < 0.0001$
	Kenya	S = 1 P = 242	S = 1 P = 242	S = 1 P = 242	S = 1 P = 242	–	–	–	–
	Nigeria	S = 4 P = 324	S = 5 P = 459	S = 6 P = 744	S = 6 P = 755	77.8% (95% CI 63.38–92.14, $I^2 = 91.9\%$, $p < 0.0001$)	52.88 (CI 34.24–71.53, $I^2 = 94.7\%$, $p < 0.0001$	48.70 (CI 35.27–62.14, $I^2 = 88.8\%$, $p < 0.0001$	45.44 (CI 33.84–57.05, $I^2 = 84.9\%$, $p < 0.001$
	Uganda	–	S = 1 P = 194	S = 1 P = 194	S = 1 P = 194	–	–	–	
Sub-group analysis by publication year	< 2019	S = 5 P = 424	S = 7 P = 996	S = 6 P = 917	S = 7 P = 1001	81.2% (95% CI 71.88–90.43, $I^2 = 85.4\%$, $p < 0.0001$)	48.3% (95% CI 27.72–68.78, $I^2 = 98.2\%$, $p < 0.0001$)	40.2% (95% CI 25.1–55.3, $I^2 = 95.1\%$, $p < 0.00001$)	48.7% (95% CI 41.01–56.45, $I^2 = 83.6\%$, $p < 0.00001$)
	≥ 2019	S = 7 P = 1997	S = 9 P = 1591	S = 11 P = 1955	S = 10 P = 1882	52.2% (95% CI 38.87–65.58, $I^2 = 95\%$, $p < 0.0001$)	43.2% (95% CI 35.5–50.9, $I^2 = 89.8\%$, $p < 0.0001$)	38.9% (95% CI 26.6–51.24, $I^2 = 97.6\%$, $p < 0.0001$)	32.6% (95% CI 26.5–38.7, $I^2 = 87.4\%$, $p < 0.0001$)
Sub-group analysis by study design	Cross-sectional	S = 7 P = 1203	S = 11 P = 1971	S = 12 P = 2256	S = 12 P = 2267	56.3%(95% CI 40.72–71.79, $I^2 = 97.1\%$, $p < 0.0001$	50.2% (95% CI 43.44–57.02, 89.3%, $p < 0.0001$	37.4% (95% CI 26.27–48.47, $I^2 = 97.5\%$, $p < 0.0001$	38.3% (95% CI 31.2–45.4, $I^2 = 92.4\%$, $p < 0.0001$
	Case–control	S = 3 P = 173	S = 5 P = 616	S = 5 P = 616	S = 5 P = 616	87.1% (95% CI 82.72–91.49, $I^2 = 0.00$, $p < 0.431$	34.6% (95% CI 3.1–66.0, $I^2 = 98.9\%$, $p < 0.0001$	44.2% (95% CI 27.48–60.85, $I^2 = 94.3\%$, $p < 0.0001$	41.96% (95% CI 29.6–54.3, $I^2 = 89.2\%$, $p < 0.0001$

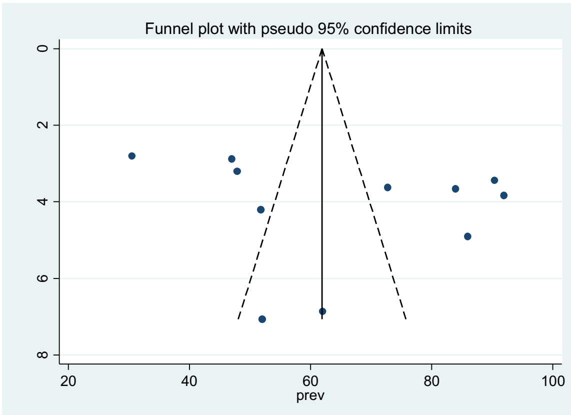

Fig. 6 Funnel plot and 95% confidence interval of undernutrition

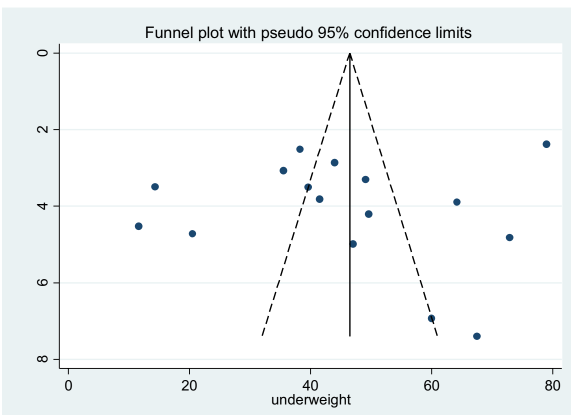

Fig. 7 Funnel plot and 95% confidence interval of underweight

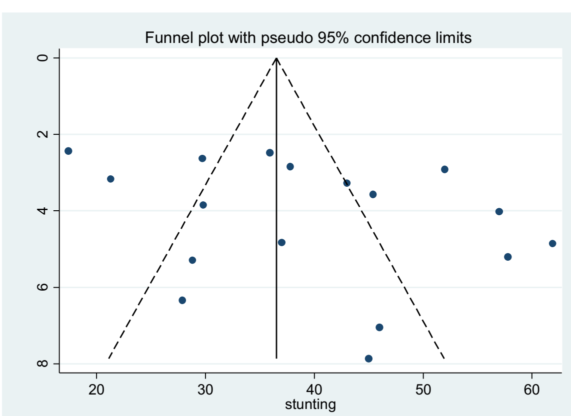

Fig. 8 Funnel plot and 95% of the confidence interval of stunting

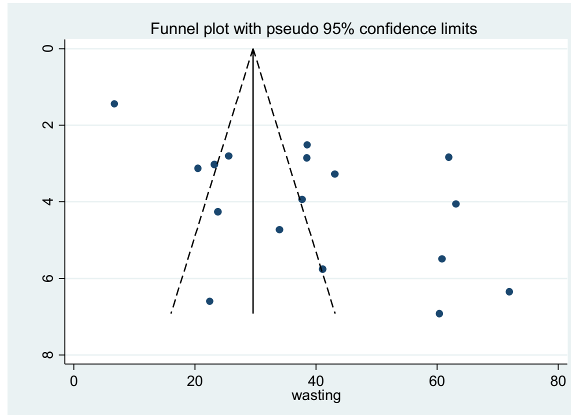

Fig. 9 Funnel plot and 95% of the confidence interval of wasting

(47.8%), and Iraq (61.8%) [40–42]. Furthermore, Dialo et al. reported that the pooled prevalence of undernutrition in children with CHD was 27.4% underweight, 24.4% stunted, and 24.8% wasted [10]. This finding is lower than the pooled prevalence of underweight (45.76%), wasting (39.37%), and stunting (39.38%) in this meta-analysis. The possible justification for this variation could be the increase in the magnitude of CHD in Africa. This review finding showed that pooled prevalence of undernutrition and its indicatories varies in publication year and country the study conducted.

Year of publication

In this review, subgroup analysis by year of publication revealed that the pooled prevalence of undernutrition was 81.2%, underweight was 48.3%, wasting 40.2%, and stunting 48.7% in children with CHD from studies conducted from 2014 to 2019 whereas in studies conducted from 2019 to 2024, the pooled prevalence of undernutrition was 52.2%, underweight 43.2%, wasting 38.9%, and stunting 32.6%. These findings indicate that undernutrition, underweight, wasting, and stunting among children with congenital heart disease remain a serious problems in Africa.

Country

In this review, subgroup analysis by country revealed that Ethiopia had a greater pooled prevalence of underweight and wasting (54.05%, 51.56%) than Egypt (23.5%, 29.5%) and Nigeria (52.9%, 48.7%) respectively. The possible reason for this increment may be the scarcity of independent healthcare facilities for children with congenital heart disease to provide special care in most public hospitals in Ethiopia, which increases admissions of children with CHD due to inadequate nutrition.

Associated actors

In this review, we found that age less than 1 year, anemia, pulmonary hypertension, and congestive heart

Table 3 summery of factors associated with undernutrition among children with congenital heart disease

Features	Variables	Number of studies	Studies included in the analysis	Odds ration with 95% CI	Heterogeneity	
					I^2 (%)	p-value
Undernutrition	Anemia	3	Labib et al. Biruk et al. Batte et al.	4.5 (1.60, 12.68)	85.9	p < 0.0001
	Age	3	Biruk et al. Temesgen et al. Redit et al.	2.78 (1.79, 4.31)	0.0	p = 0.518
	Pulmonary hypertension	3	Temesgen et al. Tamirat et al. Mulat et al.	2.76 (1.89, 4.04)	17.2	p = 0.299
	Congestive heart failure	3	Tamirat et al. Mulat et al. Batte et al.	5.98 (3.09, 11.57)	57.6	p < 0.095

failure were associated with undernutrition in children with CHD. Children aged less than 1 year were 2.61 times more prone to undernutrition than children aged greater than 1 year with CHD. The possible justification could be that children < 1 year of age are at greater risk for feeding difficulties and food intolerance as compared to children > 1 year of age. Moreover, children who survive beyond 1 year are more likely to have less severe CHD and therefore are likely at lower risk for undernutrition. In addition, CHD children with anemia were 4.5 times more prone to undernutrition than CHD children without anemia. The scientific explanation for this association could be that anemic children are at risk for iron deficiency, which is the most important mineral for child growth and development. Further, children with pulmonary hypertension were 2.76 times more likely to develop undernutrition than CHD children without pulmonary hypertension. The scientific explanation for this association could be that children with pulmonary hypertension develop gastrointestinal edema because of decreased right ventricle function leads to decreased nutrient uptake [43]. On the other hand, the odds of undernutrition in children with congestive heart failure were 5.98 higher than those in children without congestive heart failure. The possible justification might be that congestive heart failure may affect the clinical stability of children with CHD, which leads to delays in performing surgical correction. Moreover, CHD children with congestive heart failure had increased metabolic needs, increased risk of feeding intolerance, and increased risk of malabsorption among others. As a consequence, the child becomes undernourished [44].

Limitations of the study

One of the limitations of this review was that not all countries in Africa were included to investigate undernutrition in children with CHD since not enough studies have been performed in all countries of this continent. In addition, this study included only studies conducted in Africa and did not consider studies conducted outside of Africa. Furthermore, this analysis did not include papers published in languages other than English. In addition, factors associated with underweight, wasting, and stunting were not determined in this review because of the scarcity of studies. Therefore, future researchers should address these issues.

Conclusion

In this meta-analysis, the pooled prevalence of undernutrition and its indicators (underweight, wasting, and stunting) among children with CHD was high. Hence, there is still a need to improve early screening and treatment of undernutrition in children with CHD concomitant with early and comprehensive management of CHD, including medication, surgery, and ongoing care, which are necessary to alleviate the suffering of CHD children with undernutrition in Africa.

Supplementary Information

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Supplementary file 1: Searching strategies used in Pubmed engine.

Author contributions

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Mequanint Ayehu, Tamalew Alemie, Dires Birhanu, Amare Mebrat. Visualization: Tinagnework Eseyneh, Molla Getie. Writing – original draft: Mequanint Ayehu Akele, Tenagnework Eseyneh. Writing – review & editing: Mequanint Ayehu, Tenagnework Eseyneh, Daniel Sisay, Migbar Sibhat, Molla Getie, Amare Mebrat.

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Availability of data and materials
All data are available from the corresponding author upon reasonable request using this email: mequaninitayehu@gmail.com.

Declarations

Informed consent
In this study, informed consent was not required because the data were obtained from previously conducted primary studies.

Consent for publication
Not applicable.

Competing interests
The authors declare that there are no conflicts of interest.

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