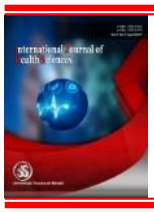

International Journal of Health Sciences

Available online at www.sciencescholar.us
Vol. 6 No. 3, December 2022, pages: 1579-1595
e-ISSN: 2550-696X, p-ISSN: 2550-6978
https://doi.org/10.53730/ijhs.v6n3.13266

Neonatal Characteristics and Conditions Contributed to Stunting: A Systematic Review and Meta-Analysis

Riyani Wulandari [a], Dewi Kartika Sari [b], Siti Fatmawati [c], Rina Sri Widayati [d]

Manuscript submitted: 16 April 2022, Manuscript revised: 10 June 2022, Accepted for publication: 08 September 2022

Corresponding Author [a]

Keywords

children;
characteristics;
conditions;
neonatal;
stunting;

Abstract

Globally, stunting is one of the most serious and challenging public health problems in the world. It is critical to have information on how to reduce stunting. Therefore, this study aimed to identify neonatal determinants of stunting among children under five years. This meta-analysis searched for observational studies published in English from 2000 to 2022 focusing on the association between neonatal characteristics and conditions affecting the incidence of stunting in children aged 0-5 years. We searched in Google Scholar, PubMed, and other online databases. Two review authors independently selected studies for inclusion, extracted data, and assessed the risk of bias in the included studies. The pooled analysis was carried out using software review manager (RevMan) 5.3. Pooled analysis indicated that children under 5 years with anemia or whoever had diarrhea had a higher odds of becoming stunted than those who did not have anemia or not ever had diarrhea and both of these results were statistically significant. Male children had a higher odds of stunting compared to female children. Our study suggest that anemia, recently had diarrhea, and boys are risk factors of stunting.

Contents

[a] Universitas Aisyiyah, Surakarta, Indonesia
[b] Universitas Aisyiyah, Surakarta, Indonesia
[c] Universitas Aisyiyah, Surakarta, Indonesia
[d] Universitas Aisyiyah, Surakarta, Indonesia

1 Introduction

Stunting is an important risk factor for early growth and health implications throughout the life course (Pun et al., 2021). Stunting is a largely irreversible outcome with long-term impacts on children and their communities. In addition to height and physical development concerns, stunted children often achieve lower developmental test scores and suffer from diminished cognitive development and reduced economic activity (de Onis & Branca, 2016; Hoddinott et al., 2013; Unicef/ WHO/The World Bank, 2019; Victora et al., 2010; Woldehanna et al., 2017).

Although stunting rates have been decreasing over the past several decades, an estimated 21.3% (144 million) of children under 5 years of age globally experienced stunted growth in 2019 (UNICEF/WHO/World Bank, 2020). Globally, Current estimates suggest that 149 million children under 5 years are stunted (Micha et al., 2020) in Thurstans et al., (2022). In recognition of the large disparities across the globe in the areas of early life nutrition and development, the World Health Assembly set a target to reduce by 40% the number of stunted children worldwide by 2025 (World Health Organization, 2014). To reach this target, information on ways to alleviate stunting in each country is essential. Recently, several observational studies have identified a large number of risk factors for poor childhood growth (Elhoumed et al., 2022; Mengesha et al., 2021; Mulyaningsih et al., 2021).

A recent comparative stunting risk-assessment analysis grouped risk factors into 5 clusters: maternal nutrition and infection, teenage motherhood and short birth intervals, fetal growth restriction and preterm birth, child nutrition, and infection, and environmental factors (Danaei et al., 2016; Yu et al., 2020). The leading global risk factors in terms of a total number of attributable stunting cases were identified as follows: fetal growth restriction (defined as being born at term and small for gestational age), unimproved sanitation, childhood diarrhea, and maternal short stature (Danaei et al., 2016; Ito, 2005). Using data from 116 countries between 1970 and 2012 (12), an econometric analysis of underlying and basic determinants identified several drivers of stunting reduction, including access to safe water, improved sanitation, gender equality, women's education, and nutritious food availability, with governance and income growth providing a supportive environment (Smith & Haddad, 2015).

There has been much variation in determinants that contribute to stunting in children aged less than 5 years. Furthermore, no study has collectively and systematically analyzed the most consistent factors associated with child stunting (Perkins et al., 2017). Therefore, this systematic review and meta-analysis study attempts to a pooled estimate of neonatal characteristics that contribute to stunting such as gender, child's illness, and breastfeeding status at the global level (Shereen et al., 2020).

2 Materials and Methods

Search strategy

The electronic databases of Embase, Google Scholar, and PubMed were systematically searched with only English keywords being searched. Keywords were obtained from MeSH and also extracted from related articles. The study syntax was formed from three components combined with the "AND" operator. The keywords component included words related to "children", "stunting", and "risk factors". The articles that were published between January 1, 2000, and August 31, 2022, were included. Our search strategy is shown in Figure 1 with a diagram of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher et al., 2009). Analyses were performed following the guidelines proposed by PRISMA.

Study selection

The authors independently conducted the search phase and screening stage (RW and DK), selection (RW, DK and SF), quality assessment (RW, DK and SF), and data extraction (RW and RS). Any disagreement was resolved by consensus, and if the disagreement was not resolved, a third expert opinion was sought. The PICO(population, intervention, control, outcome) criteria used to perform the systematic review are outlined as follows: Population (children under 5 years); intervention or exposure (anemia, breastfeeding status, diarrhea, and gender); control: (not anemia, not breastfeeding, not diarrhea, and gender); outcome: (stunting).

Inclusion and exclusion criteria

Observational studies such as cross-sectional, case-control, and cohort studies conducted on children were included in the study. Children of all ages were included in the search but for final inclusion, studies conducted on children 0 to 5 years old were selected. Studies using multivariate logistic regression with an adjusted odd ratio as effect estimate was included. Studies on stunted children, specific groups such as working children, and children referred to a hospital or clinic for stunting or other illnesses were excluded (Grantham-McGregor et al., 2007). Qualitative studies, commentaries, letters, and editorials were also excluded as well as conference abstracts, articles without the full text, and non-English reports and papers. Figure 1 shows the process to exclude unrelated articles.

Definition of variables

According to the WHO, stunting is the impaired growth and development that children experience as a result of poor nutrition, repeated infection, and insufficient psychosocial stimulation. Children are considered stunted if their height for age is more than two standard deviations below the WHO Child Growth Standards median (World Health Organization, 2020).

Anemia is defined as a child whose hemoglobin measure recently or currently is below 11mg/dl (World Health Organization, 2011). Breastfeeding status is defined as if the children had breastfed (ignoring whether it was exclusive or mixed). Diarrhea is defined as a condition if the children currently or recently had diarrhea (feces are discharged from the bowels three times or more and in a liquid form).

Data extraction and article screening

Two authors (RW and DK) independently reviewed the title and abstract of studies collected during the search phase based on the inclusion and exclusion criteria during the primary screening. At this stage, studies that did not meet the eligibility criteria were eliminated. The full texts of these articles were reviewed for inclusion criteria during the secondary screening. The data from each of the included studies were then extracted and briefly presented in table 1.

Quality assessment

Three reviewers (RW, DK, and SF) independently assessed the quality of the included studies. The Newcastle-Ottawa Scale checklist was used to assess the quality of observational studies. Articles were considered to be of high quality when the total score was ≥7, fair or good quality if the score was ≥5 and <7, and poor quality if the score was lower than 5.

Statistical analysis

All statistical analyses for evaluating the proportion/frequency of stunting were performed using Review Manager version 5.3 (RevMan) [Computer program]. Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014. As it seemed that there was heterogeneity, the random effect model was used. To evaluate the heterogeneity between studies, the Q and I^2 statistic tests were used. For the Q test,

a $P < 0.05$ was considered statistically significant and I^2 values of 75%, 50%, and 25% were considered evidence of high, moderate, and low levels of heterogeneity, respectively.

Publication bias

Funnel plots related to the publication bias are shown in figures 3, 5, 7, 9, 11, and 13.

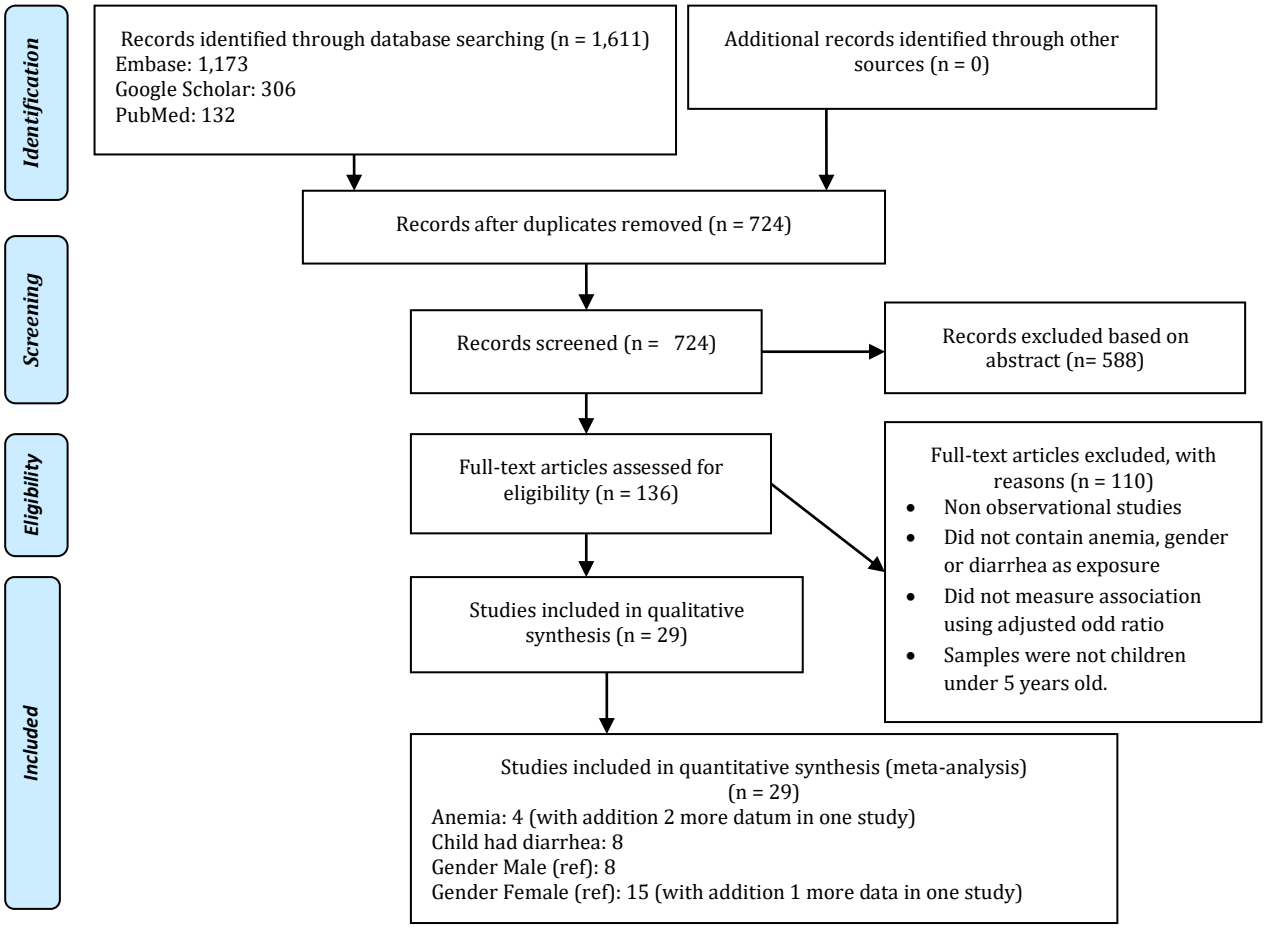

Figure 1. PRISMA Diagram Chart

3 Results and Discussions

A total of 1611 studies were identified; 1173 from Embase, 306 from Google Scholar, and 132 from PubMed. After duplication was removed, a total of 724 articles remained (887 removed by duplication). Finally, 136 studies were screened for full-text review, and 32 articles with (n = 913,315 children) were selected for the analysis (Figure 1).

Characteristics of included studies

Thirty-two studies were included in this systematic review and meta-analysis (A Balalian et al., 2017; Adhikari et al., 2019; Altare et al., 2016; Ayelign & Zerfu, 2021; Berhe et al., 2019; Chirande et al., 2015; Cruz et al., 2017; Dorsey et al., 2018; Ezeh et al., 2021; Gonete et al., 2021; Khan et al., 2019; Kismul et al., 2017; Manggala et al., 2018; Mzumara et al., 2018; Nkurunziza et al., 2017; Nutrition & Volume, 2021; Paudel et al., 2011;

Rakotomanana et al., 2017; Ramli et al., 2009; Shinsugi et al., 2015; Siswati, 2019; Sserwanja et al., 2021; Sunguya et al., 2019; Tafesse et al., 2021; Tariku et al., 2017; Tiwari et al., 2014; Torlesse et al., 2016; Vonaesch et al., 2017, 2021; Wali et al., 2020; Widyaningsih et al., 2022; Yang et al., 2018)

Table 1
Risk of bias assessment (Newcastle–Ottawa Quality Assessment Scale criteria).

No. Study	Selection				Comparability	Outcome		Quality
	Representativeness of the sample	Sample size	Non-respondents	Ascertainment of the exposure (risk factor)	Comparability of subjects in different outcome groups based on design or analysis. Confounding factors controlled	Assessment of outcome	Statistical test	
1.	1	1	0	1	2	1	1	Good
2.	1	1	0	1	2	1	1	Good
3.	1	1	0	1	2	1	1	Good
4.	1	1	0	1	2	1	1	Good
5.	1	1	0	1	2	1	1	Good
6.	1	1	0	1	2	1	1	Good
7.	1	1	0	1	2	1	1	Good
8.	1	1	0	1	2	1	1	Good
9.	1	1	0	1	2	1	1	Good
10.	1	1	0	1	2	1	1	Good
11.	1	1	0	1	2	1	1	Good
12.	1	1	0	1	2	1	1	Good
13.	1	1	0	1	2	1	1	Good
14.	1	1	0	1	2	1	1	Good
15.	1	1	0	1	2	1	1	Good
16.	1	1	0	1	2	1	1	Good
17.	1	1	0	1	2	1	1	Good
18.	1	1	0	1	2	1	1	Good
19.	1	1	0	1	2	1	1	Good
20.	1	1	0	1	2	1	1	Good
21.	1	1	0	1	2	1	1	Good
22.	1	1	0	1	2	1	1	Good
23.	1	1	0	1	2	1	1	Good
24.	1	1	0	1	2	1	1	Good
25.	1	1	0	1	2	1	1	Good
26.	1	1	0	1	2	1	1	Good
27.	1	1	0	1	2	1	1	Good
28.	1	1	0	1	2	1	1	Good
29.	1	1	0	1	2	1	1	Good

Table 2
Study characteristics and results

No.	Author (year)	Method	Country	Total sample and age	Risk factors	Control	AOR (95% CI)
1.	A Balalian et al., (2017)	Cross-sectional	Armenia	594 (aged 6 -24 months)	Anemia Gender Child had diarrhea	No Female None	0.34 (0.10-1.12) 0.80 (0.39-2.95) 2.56 (0.73-8.92)
2.	Adhikari et al., (2019)	Cross-sectional	Nepal	5083 (aged 0-59 months)	Anemia Gender	No Male	1.32 (1.12–1.56); 1.59 (1.25–2.02); 1.40 (1.12–1.75). 1.01 (0.82–1.24); 0.85 (0.64–1.14); 1.06 (0.84–1.35).
3.	Altare et al., (2016)	Cross-sectional	Tanzania	3264 (aged 6-59 months)	Gender	Female	2.17 (1.52–3.09)

4.	Ayelign et al., (2021)	Cross-sectional	Ethiopia	11,023 (aged 0–59 months)	Gender Child had diarrhea	Male No	0.78 (0.72-0.85) 0.09 (0.01-0.63)
5.	Berhe et al., (2019)	Case-control	Ethiopia	330 (aged under 5 years)	Child had diarrhea	No	4.9(1.01-34.2)
6.	Chirande et al., (2015)	Cross-sectional	Tanzania	7324 (aged 0-59 months)	Gender	Female	1.39 (1.23–1.58)
7.	Cruz et al., (2017)	Case-control	Mozambique	282 (102 cases and 180 controls) (aged 0-59 months)	Gender	Female	4.57 (2.06-10.12)
8.	Dorsey et al., (2018)	Cross-sectional	Nepal	4853 (aged 6-59 months)	Gender	Male	1.09 (0.93-8.44)
9.	Ezeh et al., (2021)	Cross-sectional	Nigeria	233,682 (under 5 years)	Gender Child had diarrhea	Female No	1.37 (1.21–1.55) 1.47 (1.25–1.73)
10.	Gonete et al., (2021)	Cross-sectional	Ethiopia	422 (newborns)	Gender	Female	2.916 (1.629-5.218)
11.	Khan et al., (2019)	Retrospective cross-sectional	Pakistan	3071 (aged 0-59 months)	Gender Child had diarrhea	Female No	1.47 (1.14-1.89) 1.06 (0.79–1.40)
12.	Kismul et al., (2017)	Retrospective cross-sectional	Democratic Republic of Congo	9369 (aged under 5 years)	Gender Child had diarrhea	Male None	0.81 (0.70-0.94) 1.11 (0.89-1.39)
13.	Manggala et al., (2018)	Cross-sectional	Indonesia	166 (aged 24-59 months)	Breastfeeding status	Yes	2.795 (0.40-19.66)
14.	Mzumara et al., (2014)	Cross-sectional	Zambia	12,328 (aged 0-59 months)	Gender	Male	0.80 (0.73-0.88)
15.	Nkurunziza et al., (2014)	Cross-sectional	Burundi	6199 (aged 6-23 months)	Gender	Female	1.5 (1.4-1.8)
16.	Paudel et al., (2021)	Case-control	Nepal	118 as cases and 236 as controls (aged 6-59 months)	Child had diarrhea	None	7.46 (2.98-18.65)
17.	Rakotomanana et al., (2017)	Retrospective cross-sectional	Madagascar	4774 (aged under 5 years)	Gender Anemia	Male No	0.85 (0.75–0.98) 1.25 (1.05–1.48)
18.	Ramli et al., (2009)	Cross-sectional	Indonesia	2168 (aged 0-59 months)	Gender	Male	0.74 (0.59-0.93)
19.	Siswati et al., (2018)	Cross-sectional	Indonesia	18,225 (aged 0-59 months)	Gender	Female	1.03 (0.96-1.12)
20.	Shinsugi et al., (2015)	Retrospective cross-sectional	Southeastern Kenya	404 (aged under 5 years)	Gender	Male	1.52(0.92 - 2.52)
21.	Sserwanja et al., (2021)	Cross-sectional	Sierra Leone	4045 (aged under 5 years)	Gender	Female	1.37 (1.12-1.66); 1.48 (1.06-2.08)
22.	Sunguya et al., (2019)	Retrospective cross-sectional	Tanzania	41,297 (aged under 5 years)	Gender	Male	0.77 (0.68-0.87)
23.	Tafesse et al., (2021)	Case-control	Ethiopia	237(79 cases and 158 controls) (aged 6–59 months)	Gender Child had diarrhea	Female No	2.37 (1.224–4.59) 2.71 (1.42–5.162)
24.	Torlesse et al., (2016)	Cross-sectional	Indonesia	1366 (aged 0-23 months)	Gender	Female	1.45 (1.11 - 1.90)
25.	Vonaesch et al., (2021)	Case-control	Antananarivo, Madagascar and Bangui, Central African Republic	175 + 194 stunted and 237 + 230 non-stunted control; 424 and 409 (aged 2-5 years)	Anemia Child had diarrhea	No No	2.20 (1.27-3.82) 15.15 (1.48-154.58)
26.	Vonaesch et al., (2017)	Cross-sectional	Bangui, Central African Republic	414 (aged five years or less)	Gender	Male	0.61 (0.38-0.94)
27.	Wali et al., (2020)	Cross-sectional	South Asia	564,518 (aged 0–59 months)	Gender Child had diarrhea	Female No	1.05 (0.96-1.14) 1.12 (0.99-1.27)
28.	Widyaningsih et al., (2022)	Cross-sectional	Indonesia	3387 (aged 0–59 months)	Gender	Female	1.18 (1.02-1.36)
29.	Yang et al., (2018)	Cross-sectional	Uganda	14,747 (aged under 5 years)	Gender Child had diarrhea	Female No	1.42 (1.31-1.54) 1.17 (1.11-1.23)

Of them 1 study were done in Armenia (A Balalian et al., 2017), 1 in Burundi (Nkurunziza et al., 2017), 2 in Central African Republic (Vonaesch et al., 2017, 2021), 1 in Democratic Republic of Congo (Kismul et al., 2017), 5 in Ethiopia (Ayelign & Zerfu, 2021; Berhe et al., 2019; Gonete et al., 2021; Tafesse et al., 2021), 5 in

Indonesia (Manggala et al., 2018; Ramli et al., 2009; Siswati et al., 2015; Torlesse et al., 2016; Widyaningsih et al., 2022), 1 in Kenya (Shinsugi et al., 2015), 1 in Madagascar (Rakotomanana et al., 2017), 1 in Mozambique (Cruz et al., 2017), 4 in Nepal (Adhikari et al., 2019; Dorsey et al., 2018; Paudel et al., 2021), 1 in Nigeria (Ezeh et al., 2021), 1 in Pakistan (Khan et al., 2019), 1 in Sierra Leone (Sserwanja et al., (2021), 1 in South Asia (Wali et al., 2020), 3 in Tanzania (Altare et al., 2016; Chirande et al., 2015; Sunguya et al., 2019), 1 in Uganda (Yang et al., 2018), 1 in Zambia (Mzumara et al., 2018).

Based on the study design used 24 studies were done by cross-sectional study design (A Balalian et al., 2017; Adhikari et al., 2019; Altare et al., 2016; Ayelign & Zerfu, 2021; Chirande et al., 2015; Dorsey et al., 2018; Ezeh et al., 2021; Gonete et al., 2021; Khan et al., 2019; Kismul et al., 2017; Manggala et al., 2018; Mzumara et al., 2018; Nkurunziza et al., 2017; Paudel et al., 2011; Rakotomanana et al., 2017; Ramli et al., 2009; Shinsugi et al., 2015; Siswati, 2019; Sserwanja et al., 2021; Sunguya et al., 2019; Tafesse et al., 2021; Torlesse et al., 2016; Vonaesch et al., 2017; Wali et al., 2020; Widyaningsih et al., 2022; Yang et al., 2018) and while other 5 studies were conducted by case-control study design (Berhe et al., 2019; Cruz et al., 2017; Paudel et al., 2011; Tafesse et al., 2021; Vonaesch et al., 2021). All studies were published between 2009 and 2021.

The total number of participants in the included studies ranged from 116 (Gonete et al., 2021) to 5951 (Vonaesch et al., 2017) (Table 1).

The association between anemia and stunting among children under five years

We found that 6 studies reported an association between anemia and stunting among children under five years. Subgroup analysis using random-effects model analysis was found to be AOR 1.38 (95%CI= 1.18-1.62); I^2 = 53%; p<0.0001) (Figure 2). Using study design as criteria subgroup analysis was done.

Publication bias

Subjectively the funnel plot indicated symmetrical distributions which indicate the absence of publication bias (Figure 3).

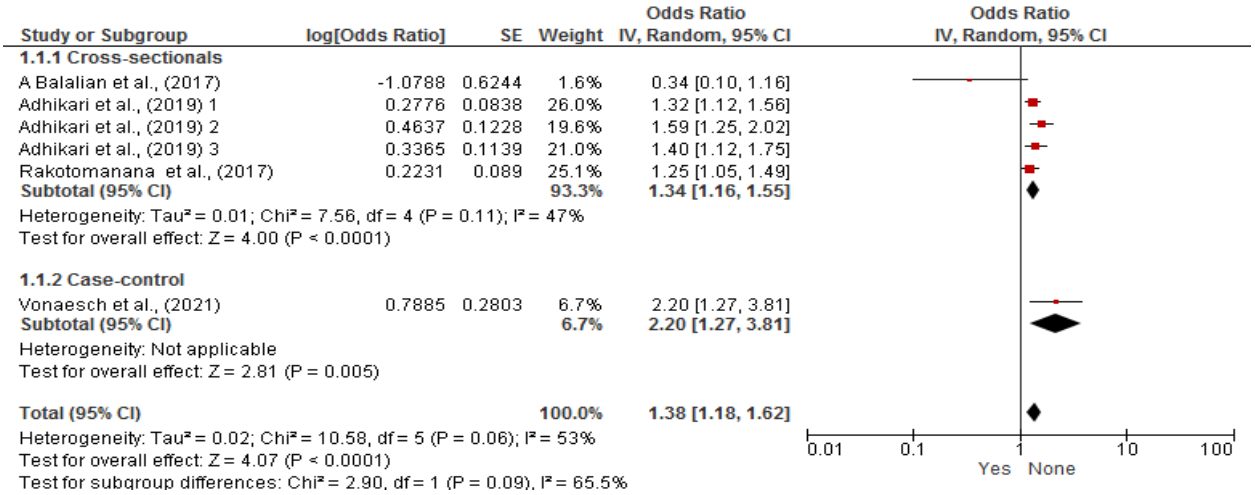

Figure 2. *forest plot of the association between anemia and stunting among children under five years*

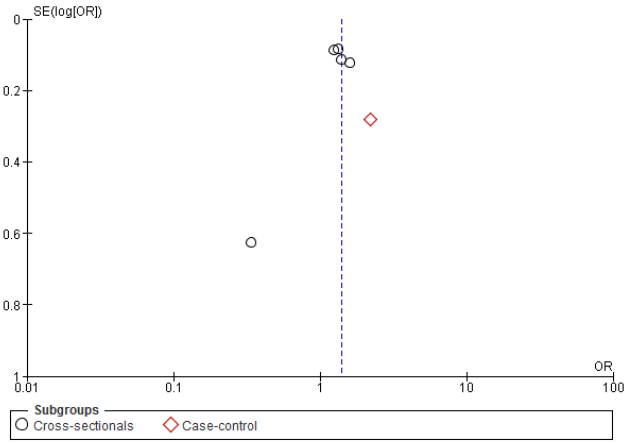

Figure 3. *funnel plot of the association between anemia and stunting among children under five years*

The association between diarrhea and stunting among children under five years.

We found that 11 studies reported the association between diarrhea and stunting among children under five years. Subgroup analysis analysis using random-effects model analysis was found to be AOR 1.36 (95%CI= 1.13-1.62); I^2 = 78%; p= 0.0008) (Figure 4). Using study design as criteria subgroup analysis was done.

Publication bias

Subjectively the funnel plot indicated symmetrical distributions which indicate the absence of publication bias (Figure 5).

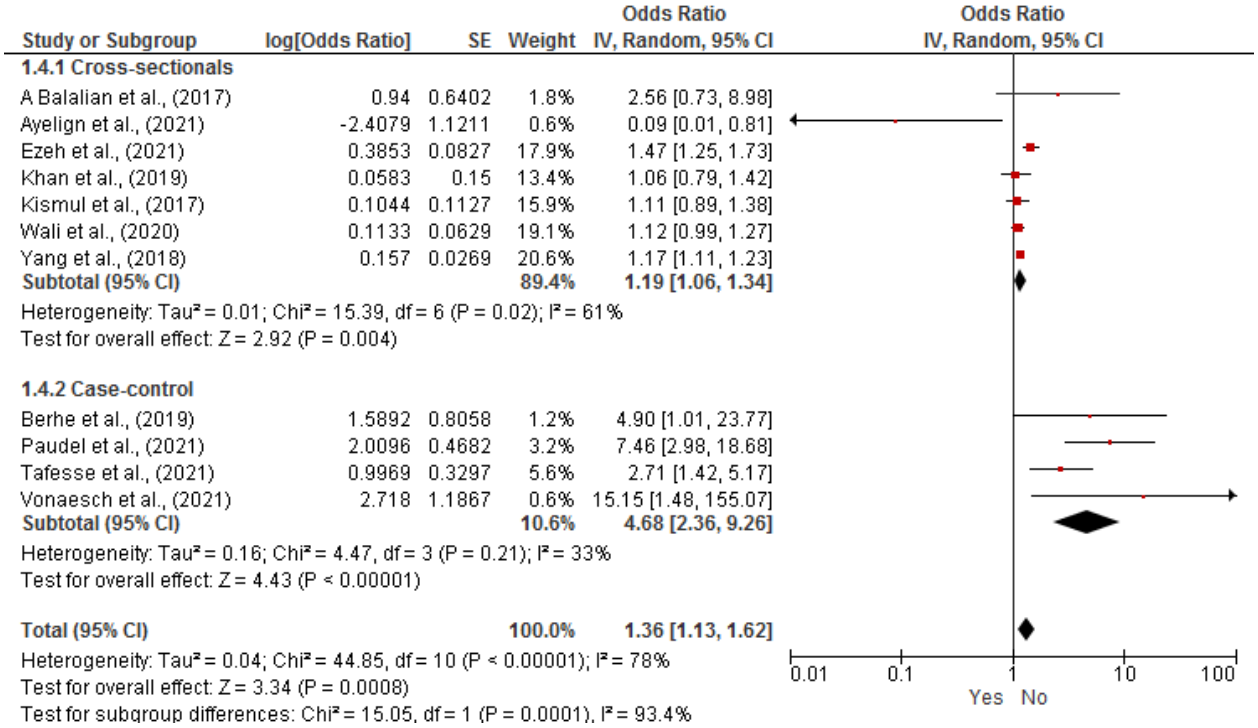

Figure 4. *forest plot of the association between diarrhea and stunting among children under five years*

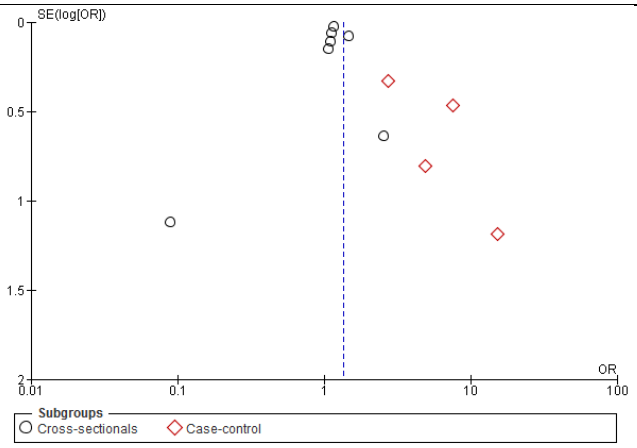

Figure 5. *funnel plot of the association between diarrhea and stunting among children under five years*

The association between gender and stunting among children under five years

We found that 23 studies reported an association between gender and stunting among children under five years. Eight studies reported "female" as intervention and "male" as control Subgroup analysis using random-effects model analysis was found to be AOR 0.86 (95%CI= 0.79-0.93); I2 = 64%; p= 0.0002) (Figure 6). Using study design as criteria subgroup analysis was done.

Fifteen studies reported "male" as intervention and "female" as control Subgroup analysis using random-effects model analysis was found to be AOR 1.41 (95%CI= 1.26-1.57); I^2 = 88%; p<0.00001) (Figure 8). Using study design as criteria subgroup analysis was done.

Publication bias

Subjectively the funnel plot indicated symmetrical distributions which indicate the absence of publication bias (figures 7 & 9).

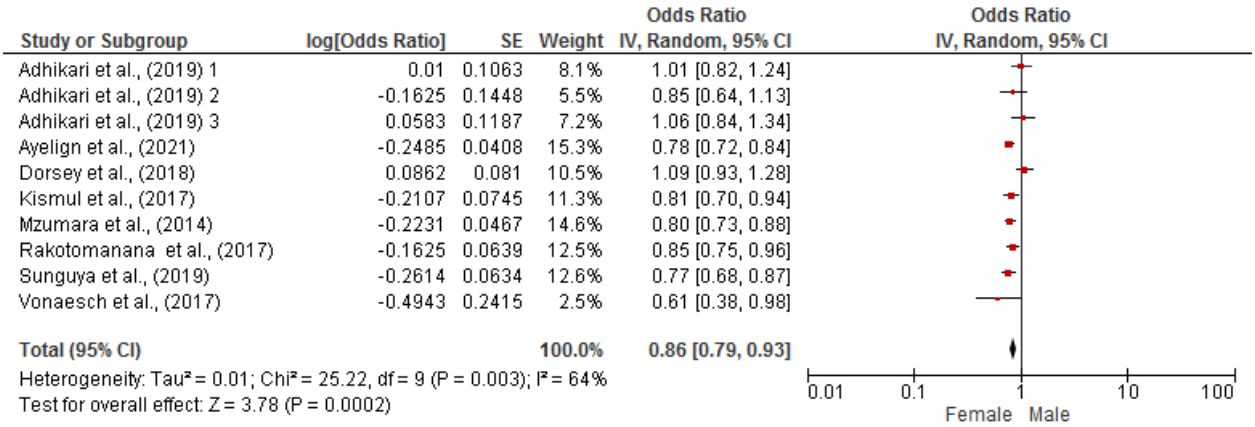

Figure 6. *forest plot the association between gender with male as control and stunting among children under five years*

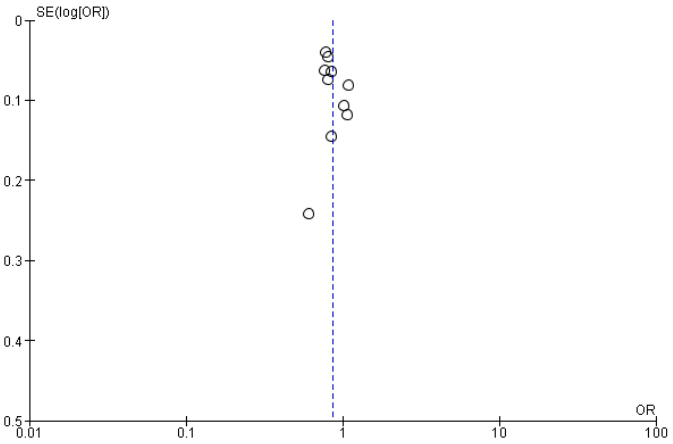

Figure 7. *funnel plot the association between gender with a male as control and stunting among children under five years*

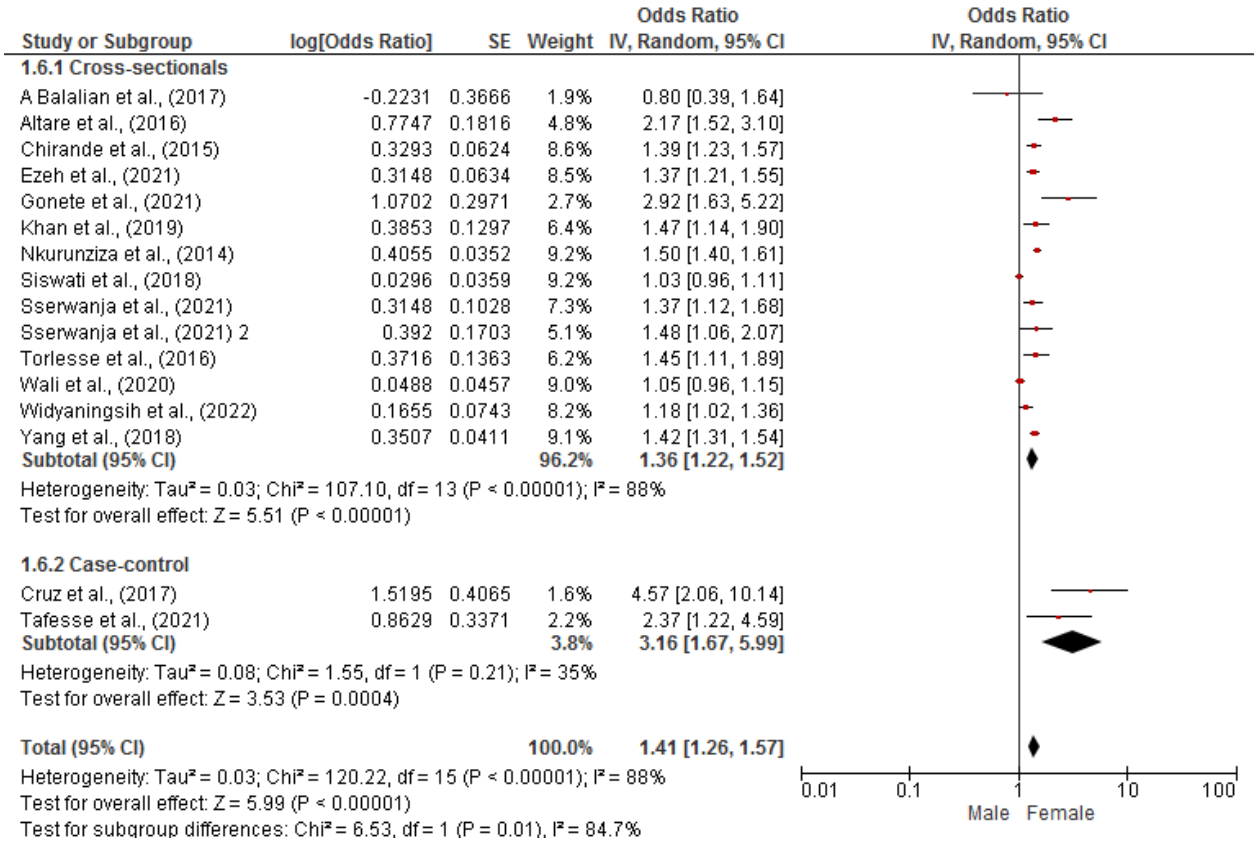

Figure 8. *forest plot the association between gender with a female as control and stunting among children under five years*

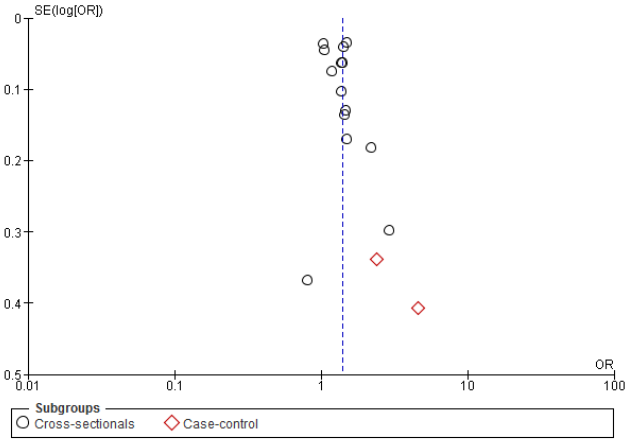

Figure 9. *funnel plot the association between gender with a female as control and stunting among children under five years*

Our analysis showed that children under 5 years with anemia had a higher odds of stunting. This result is statistically significant. Balarajan et al. (2011), stated stunting was found significantly associated with anemia among school children. Stunted children were two times more likely to be anemic than non-stunted children. This might be due to the long term effect of low intake of both macro and micronutrients, especially iron, vitamin B12, folate and other minerals and vitamins. This was in line with studies by Getaneh et al. (2017), Gutema et al. (2014), and Mesfin et al. (2015).

Children who ever had diarrhea had a higher odds of stunting than whoever did not and it was statistically significant. The effect of diarrhea on stunting was consistent across studies. This was similar with study by Martorell et al. (1994), reported that it is plausible that a higher cumulative burden of diarrhea increases the chance of childhood stunting.

This study reported that male children had higher odds of stunting compared to female children. Both of our results regarded this association was significant. Wamani et al. (2007), also stated that male children in households of the poorest were more likely to be stunted compared to females in the same group, but the pattern was not consistent in all studies.

Speculation on observed sex differences focuses primarily on behavioral patterns. For instance in an extensive analysis of gender bias in undernutrition in sub-Saharan Africa, Svedberg proposed that the slight anthropometric advantage shown by girls, women, or both in many countries may suggest a historical pattern of preferential treatment of females due to the high value placed on women's agricultural labour (Svedberg, 1990). Cronk proposed that favoritism towards daughters occurred as a result of lower socioeconomic status based on a study of gender biases among the Mukogodo of Kenya (Cronk, 1989). However, there are studies that show that sons are more socially valued than daughters (Crognier et al., 2006; Bocheliuk et al., 2021), including dietary discrimination (Leslie et al., 1997), thereby dispelling conclusions of a nutritionally advantaged position of female over male children.

A biological explanation is an alternative hypothesis for the difference's cause. Both morbidity and mortality are consistently higher in males than females in early life, according to epidemiological studies in neonatology and in cohorts of pre-term infants and children, with the differences persisting after adjusting for gestational age and body size, and being more pronounced in pre-term subjects (Chen et al., 1993; Elsmén et al., 2004; Kilbride & Daily, 1998; Synnes et al., 1994). Aside from the specific sex-chromosome factors, the underlying mechanisms to why male gender is associated with increased neonatal mortality and morbidity is poorly understood (Green, 1992; Synnes et al., 1994). However, the reported male predominance in both symptomatic and asymptomatic morbidity suggest that boys generally, are more vulnerable, which could partly explain our findings (Green, 1992).

4 Conclusion

This study reveals that children under 5 years with anemia or recently had diarrhea are more likely to become stunted. Male children also had a higgher odds of become stunted than females, which might suggest that boys are more vulnerable to health inequalities than their female counterparts in the same age groups. It raises interesting issues that mandate further research.

Acknowledgments
This work was supported by authors personal fund.

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Biography of Authors

Riyani Wulandari
is currently working as a lecturer in the school of Nursing profession at Universitas Aisyiyah, Surakarta, Indonesia. She graduated from a master's degree in Nursing.
Email: riyaniwulandari24@gmail.com

Dewi Kartika Sari
is currently working as a lecturer in the school of Nursing profession at Universitas Aisyiyah, Surakarta, Indonesia. She holds a master's degree in Nursing.
Email: nswieka@yahoo.co.id

Siti Fatmawati
is currently working as a lecturer in the school of Nursing profession at Universitas Aisyiyah, Surakarta, Indonesia. She holds a master's degree in Nursing.
Email: fatmawatie45@gmail.com

Rina Sri Widayati
is currently working as a lecturer in the school of profession in Midwifery at Universitas Aisyiyah, Surakarta, Indonesia. She graduated from Master of Public Health.
Email: rinasriwidayati@gmail.com