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REVIEW

Potential risk of stunting in children under five years living by the riverside: A systematic review

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ABSTRACT

Introduction: Stunting, or linear growth failure, is defined by a height-for-age z-score of below -2SD according to WHO growth standard. Stunting can have short-, medium-, and long-term consequences. Rivers have an important role in human life. In several riverside areas, households still depend on the river for their livelihoods and health. This study aimed to explore the prevalence of stunting in children living by the riverside and its related factors. **Methods:** Epidemiological studies published from PUBMED, MEDLINE via EBSCOHost, Science Direct, ProQuest, and Research Gate databases were systematically searched. The publication period was not restricted. Only open-access and English articles were examined. **Results:** A total of 20 from 1200 studies were reviewed. The prevalence of stunting ranged from 20% to 48.3%. The other outcomes besides stunting were wasting and underweight status. There were 83 risk factors studied, and the most studied variables were age, gender, diarrhoea, water source, parent's education, immunisation, and inappropriate complementary feeding practices (6 to 13 studies). Household water sources from rivers and economic status were consistently correlated with stunting. Majority of the risk factors studied were related to nutrition. From the environmental aspect, the most studied risk factors were water sources and sanitation. **Conclusion:** Children living by the riverside face a significant risk of stunting attributed to the consistent correlation between household water sources from rivers and economic status, affecting various aspects of daily life beyond drinking water. Future research is needed to examine the impact of environmental factors and the behaviours of riverside communities.

Keywords: children, risk factor, river, riverside, stunting

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INTRODUCTION

Stunting is the failure to achieve height growth, measured by a height-for-age z-score (HAZ) of <-2 standard deviation (SD) according to the World Health Organization (WHO) growth standards (Prawirohartono & Press, 2021; Vonaesch *et al.*, 2018). In children, it is associated with many factors, including socioeconomic factors, dietary intake, recurrent infections, maternal nutritional status, infectious diseases, micronutrient deficiencies, and the environment (Stevens, Finucane, & Paciorek, 2016; WHO, 2018a).

Growth impairment can occur even in the foetus (Prendergast & Humphrey, 2014). The average length-for-age z-score (LAZ) for a baby in developing countries is -0.5 and will continue to decrease, even reaching -2.0 at the age of 18-24 months (Victora *et al.*, 2010). However, growth impairment can continue after the age of 24 months when socio-economic influences (Alderman & Headey, 2018; Rajpal *et al.*, 2020), education and home environment such as the use of a latrine or toilet can have a great effect between the ages of 24-59 months (Alderman & Headey, 2018; de Onis & Branca, 2016).

The disruption of growth of a child's height can have short-term (Olofin *et al.*, 2013), medium-term (Nguyen *et al.*, 2021; Prendergast & Humphrey, 2014) and long-term consequences (De Lucia *et al.*, 2018; Prendergast & Humphrey, 2014). In the short term, stunting can increase morbidity and mortality from infectious diseases, especially pneumonia and diarrhoea (Prendergast & Humphrey, 2014). The medium-term impact is related to child development such as cognitive abilities, education, and child behaviour (Cheung & Ashorn, 2010; Nguyen *et al.*, 2021; Prendergast & Humphrey, 2014). Metabolic syndrome, usually associated with excess nutrition, is more common in adults who were stunted in early childhood than in those with normal growth (Victora *et al.*, 2008).

Globally in 2016, as many as 22.9% or 154.8 million children under the age of 5 years suffered from stunting. In the same year, as many as 87 million stunted children lived in Asia, 59 million in Africa, and 6 million in Latin America and the Caribbean. Five sub-regions with child stunting rates that exceed 30% are West Africa (31.4%), Central Africa (32.5%), East Africa (36.7%), South Asia (34.1%), and Oceania (38.3%; excluding Australia and New Zealand) (WHO, 2018a). In 2018, around 22% of children under five worldwide were stunted. A 40% reduction in the number of stunted children is the global target for 2025 (Lissauer & Carroll, 2021).

Rivers have an important role in life. Although not in all countries, households still depend on natural capital for their livelihoods and health, including riverside areas (Ricketts *et al.*, 2017). The river is a source of life used by a community for water resource, recreation, irrigation, and transportation (Ikhsan *et al.*, 2021). In certain areas, the environmental health conditions of people living by the riverside do not meet WHO standards (Shinta *et al.*, 2020). This is due to the lack of adequate sanitation facilities (Rahmadani & Ridlo, 2020) and disposal of solid and liquid waste (Bartram & Ballance, 1996; Pratama, *et al.*, 2020; Verbyla *et al.*, 2021). Additionally, people still defecate in public places and throw their trash into rivers (Shinta *et al.*, 2020; Zahtamal *et al.*, 2020). These situations will certainly have an impact on the health status of people living by the riverside, especially children.

A systematic literature review explored the prevalence of stunting and its risk factors in children who live by the riverside. Thus, the questions posed for this review were "what is the magnitude of the stunting problem in children

under five who live by the riverside" and "what are the risk factors associated with stunting?"

MATERIALS AND METHODS

A review protocol was developed following the preferred reporting items for systematic review and meta-analysis PRISMA 2020 (Page *et al.*, 2021). Literature searches were conducted in the following databases: PUBMED, MEDLINE via EBSCOHost, Science Direct, ProQuest, and ResearchGate. The publication period was not restricted. Eligibility was limited to peer-reviewed scientific articles published in the English language and open-access articles. Review articles, conference proceedings, book chapters, thesis dissertations, case reports, and all non–English language materials were excluded. The search used the following terms: ("children under five" OR child* OR preschool OR toddler*) AND ("Riverside" OR river* OR watershed*) AND ("risk factor" OR risk OR "determinant") AND (Stunt* OR "growth disorders" OR "growth impairment" OR "growth failure" OR "growth faltering"). Another search strategy was used for the databases by limiting the number of Boolean connectors, such as "children under five" AND ("risk factor" OR determinant) AND "river" AND "stunting".

The reviews included all epidemiological studies without being limited to the study design. The last literature search was 10th November, 2022. Data were organised according to the author, year of publication, country or national setting, sample size, study design, stunting risk factor, and outcomes. The eligible studies had to match the inclusion and exclusion criteria according to the PEO (Population, Exposure, and Outcome) approach (Table 1) (Munn *et al.*, 2018). Qualitative studies and studies which had similar results from the same author(s) were excluded. The EndNote X9 reference manager program filtered duplicate studies and excluded research protocol or review studies.

Table 1. The PEO Criteria for inclusion studies

Parameter	*Inclusion criteria*
Population	Children under five living at riverside
Exposure	Stunting risk factor or determinant
Outcome	Stunting
Study design	Epidemiological study

RESULTS

A total of 1200 studies from five databases were retrieved, while 39 and 56 studies were excluded because of duplication and research protocol or review studies, respectively. The next stage was filtering articles based on title, abstract and keywords. A total of 1054 articles were excluded because of they did not meet the specified inclusion criteria. Articles were excluded at this stage because they did not include the author's name (usually in large-scale or global study and collaborator authors), the outcome studied was not stunting (even though the study's sample was children under five years old), the location was not in a riverside area, and the sample was children aged more than 5 years. The number of studies that were assessed in full text were 51, but only 20 met the inclusion criteria (Figure 1).

Table 2 shows the summary of studies included in this review. The studies' publication year range was from 2006 to 2022. Geographically, most of the research was conducted in African countries; studies were also conducted in several countries in South America, South Asia, and Southeast Asia. Cross-sectional study was the most common

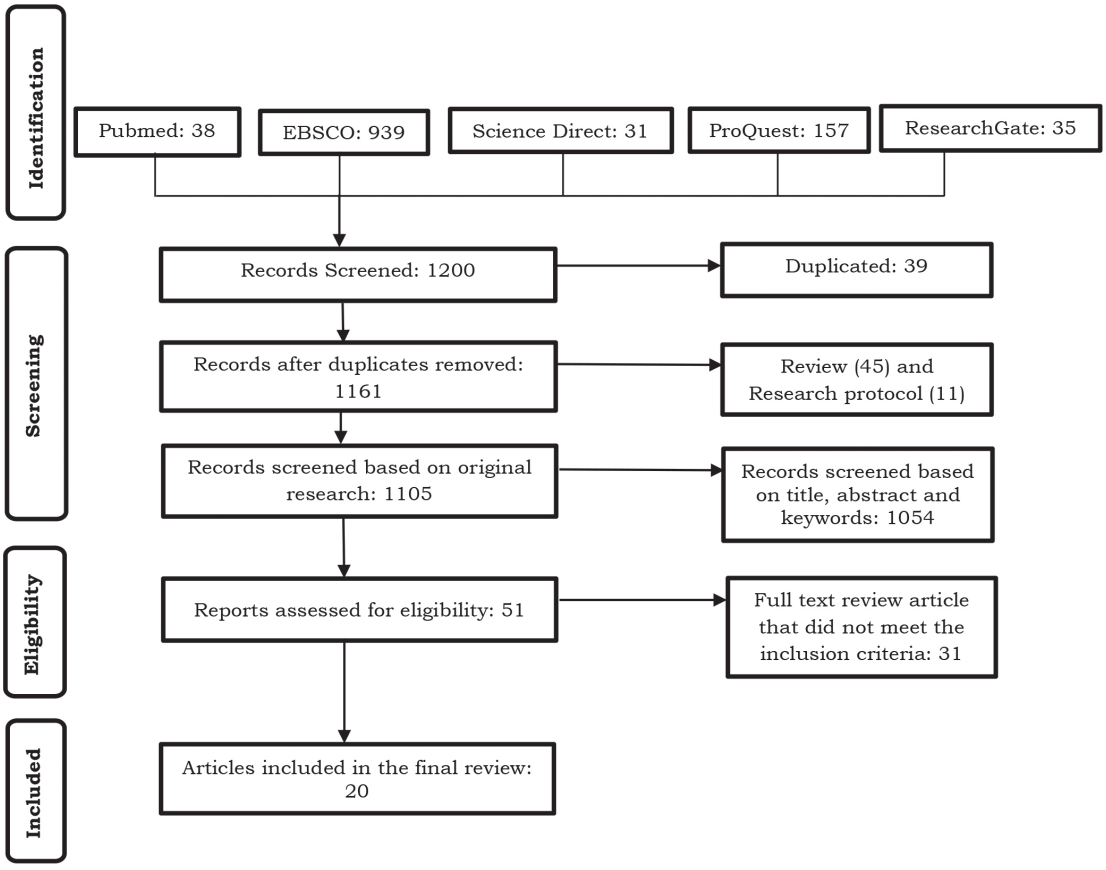

Figure 1. PRISMA flowchart and selection process

study design. However, two cohort studies and one spatial study were discovered. This review included the space-time analysis study because it compared the prevalence of stunting by the riverside and other areas.

The prevalence of stunting ranged from 20% to 48.3%. The other outcomes shown besides stunting were wasting and underweight status. There were 83 risk factors studied, with the most studied variables being age, gender, diarrhoea, water source, parent's education, immunisation, and inappropriate complementary feeding practices (6 to 13 studies). Table 3 describes the stunting risk factors studied (from the most studied to the least).

Household water sources from rivers and economic status were consistently correlated with stunting. Majority of the risk factors studied were related to nutrition, such as food diversity, breastfeeding and complementary food, as well as socio-demographic factors. From the environmental aspect, the most studied risk factors were water sources and sanitation. Figure 2 compares the significant and insignificant factors for stunting in children under five.

In Figure 2, socioeconomic class and water sources were consistently related to stunting. Although economic status and water sources had not been studied much, they need to be considered as important risk factors for

Table 2. Summary of studies

Author	*Title*	*Country*	*Design study*	*Sample size*	*Result*
Kinyoki *et al.*, 2016	Assessing comorbidity and correlates of wasting and stunting among children in Somalia using cross-sectional household surveys: 2007 to 2010	Somalia	Cross-sectional study	73,778 children under five years	• In geographical variation, a high risk of all forms of malnutrition in the southern regions, especially around the two main rivers of Juba and Shebelle, compared to the Northern regions of Somalia. • Prevalence of stunting 31%, underweight 58%, and wasting 21%. • (+): diarrhoea, acute respiratory infection, female child, child age, age of mother, household size, number under 5, female household head, high carbohydrate foods, high protein foods, fats, fruits, and vegetables.
Wachukwu-Chikodi & Sonye, 2022	Assessment of Complementary Feeding Practices and Nutritional Status of Children (0-24 months) in Akuku Toru Local Government Area of Rivers State, Nigeria	Akuku Toru Local Government Area of Rivers State, Nigeria	Descriptive Cross-sectional study	210 infants 0–24 months	• Prevalence of stunting: 30%, underweight 39%, and wasting 31%. • There was a significant association between inappropriate complementary feeding practices and under-nutritional status of infants. • This study also found that children were at high risk of malnutrition when introduced to inappropriate complementary feeding practices such as complementary feeding at age of 0–3 months and not receiving meal diversity.
Fernandes, de Castro & Sartorelli, 2017	Associated factors of malnutrition among African children under five years old, Bom Jesus, Angola	Bom Jesus, Angola	Cross-sectional study	742 children under 5 years	• Prevalence of stunting: 22%, underweight 13%, and wasting 7%. • (+): Child's age, male child, source of water from river or lake, parasite expulsion, and ear infection (-): number of father's children, fathers living with another family, parent's age, father's ethnicity, number of parent's children, mother's occupation, electricity, mother education level, number of mother's children, number of siblings under 5 years old.

Table 2. Summary of studies (continued)

Author	*Title*	*Country*	*Design study*	*Sample size*	*Result*
Udoh & Amodu, 2016	Complementary feeding practices among mothers and nutritional status of infants in Akpabuyo Area, Cross River State Nigeria	Akpabuyo Area, Cross River State Nigeria	Cross-sectional study	330 pairs of mothers and children aged 6-11 months	• Prevalence of stunting 24.6%, underweight 33.3%, and 26.4% wasting. • (+): Children who did not receive the minimum feeding frequency were more likely to be stunted than their peers who received the minimum feeding frequency and child's age. (-): milk feeding frequency for non-breastfed child, hand washing with soap, diarrhoea in last 2 weeks, vitamin, minerals, supplements, hospital medicine offered in the previous 7 days. Child was sick in the previous 1 month, mother's age, mother's occupation, place of work, mother's income, number of people in the household, parity, child's gender, and birth order of child.
Rukambile *et al.*, 2020	Determinants of diarrhoeal diseases and height-for-age Z-scores in children under five years of age in rural central Tanzania	Tanzania	Kohort study	493 children under five years of age	• The proportion of stunted children among the 24-34; 35-45; and 46-56 months age groups were 47.3%, 48.3%, and 33.3%, respectively. • The mean of diarrhoea incident was 2.3 with range of 0-16 incidents over 24 months • The source of water and animal kept inside the house overnight significantly correlated with both diarrhoea and stunting. • (+): language group of head of household, handwashing method in running water, hanging utensils after washing.
Guptan *et al.*, 2007	Early introduction of water and complementary feeding and nutritional status of children in Northern Senegal	Nothern Senegal	Cross-sectional study	374 children aged 6-23 months	• Prevalence of stunting was 20% and wasting 16%. • (+): age, source of water not from river/ pond. River or pond as the primary source of drinking water was also associated with recent diarrhoea.

Table 2. Summary of studies (continued)

Author	*Title*	*Country*	*Design study*	*Sample size*	*Result*
Kinyoki *et al.*, 2016	Environmental predictors of stunting among children under-five in Somalia: cross-sectional studies from 2007 to 2010	Somalia	Spatial – time study	Data from household nutritional surveys in Somalia from 2007 to 2010 with a total of 1,066 clusters covering 73,778 children aged 6-59 months	• Overall, the distribution of stunting in Somalia suggested substantial spatial heterogeneity with prevalence consistently higher in the regions of the South-Central zones compared to those in the North where Agro-pastoral and riverine livelihoods found in South Central zone The regions that consistently exceeded 40% prevalence were Bay, Gedo, Bakool, Mudug, Lower and Upper Juba. All these regions are in the South-Central zone.
Kehinde *et al.*, 2021	Nutritional status of under five children in the Cameroonian Refugee Settlement in Ogoja, Cross River State, Nigeria	Nigeria	Descriptive cross-sectional study	211 children aged 6-59 months	• Prevalence of stunting was 41.7%, underweight 38.4%, and 26.8% wasting. • An overview of the risk of stunting based on the characteristics of the mother and household were as follows: 55.8% mothers' age was 25-34 years, 79.8% mothers age at delivery of first child was 14-17 years, 96.2% households had one child under five years old, 45.2% household often hungry, 70.2% households had 5 or more family members. • An overview of the risk of stunting based on characteristics and caring practices of under-five children were as follows: mean of ages was 30.33 months, 56.7% children were females, 83.2% of children under-five were exclusively breastfed for six months. Majority (55.8%) of children under-five were not fully immunised, and 29.8% had diarrhoea preceding two weeks.

Table 2. Summary of studies (continued)

Author	*Title*	*Country*	*Design study*	*Sample size*	*Result*
Sulaiman *et al.*, 2018	Prevalence and determinants of undernutrition among children under 5-year-old in rural areas: A cross-sectional survey in North Sudan	River Nile state (RNS) in North Sudan	Cross-sectional study	1477 children under 5 years	• Prevalence of stunting was 42.5%, underweight 32.7%, and 21% wasting. • Stunting was highest among 48–60 months age group. • Based on gender, boys had poorer indicators of undernutrition. • (+): age, gender, poorer household sanitation, and socio-economic class. The number of family members, less distance between families, and the baby being weaned suddenly are considered risk factors for malnutrition.
Adeniran *et al.*, 2017	Schistosomiasis, intestinal helminthiasis and nutritional status among preschool-aged children in sub-urban communities of Abeokuta, Southwest, Nigeria	Abeokuta, Southwest, Nigeria	Cross-sectional study	241 children aged 0-71 months	• Prevalence of stunting was 39.5%, underweight 22.8%, and 11.4% wasting. • There was no significant correlation between infected intestinal helminths, schistosomiasis, co-infection of schistosomiasis and intestinal helminths with stunting. • Mean z-scores were generally lower in infected than non-infected children, but not significantly different. • Children exposed to river were 61%. Bathing (20.2%) was the major activity predisposing to infection, and 63.6% bathed with water from the river at home. 13.2% households still depended solely on water from the river for domestic usage. • From sanitation aspect, 16.2% of the parent/caregiver engaged in open defaecation in surrounding bushes and 1.8% directly into the river. • From hygiene aspect, only 9% children had washed their hands with soap before eating. 63.55 had dirty fingers, and 92.3% had slippers/shoes.

Table 2. Summary of studies (continued)

Author	*Title*	*Country*	*Design study*	*Sample size*	*Result*
Mengesha *et al.*, 2021	The prevalence of stunting and associated factors among children under five years of age in Southern Ethiopia: Community based cross-sectional study	Southern Ethiopia	Cross-sectional study	660 children under five years	• Prevalence of stunting was 37.7% • (+): age (older), family size (more than five members), number of under-five children in the household (two or more), wealth status, source of drinking water (river, pond, or a spring), access to diversified diet, and household food security status.
Sanchez *et al.*, 2015	Needs, acceptability, and value of humanitarian medical assistance in remote Peruvian Amazon riverine communities	Peruvian Amazon Basin	Cross-sectional health assessment	457 children under five years	• Prevalence of stunting 20%, wasting 3%, mean of Hb 11.2g/dL, and prevalence of anaemia 37%. Prevalence of one or more intestinal parasites was 62%. • Immunisation and reported health status: only 71% of children over 1 year completed the full Peruvian immunisation schedule. The caretakers reported that 49% of their children had a cough, 34% had a fever, and 29% had diarrhoea 2 weeks before surveys. They also reported that 61% of their children had good physical well-being and 67% had good emotional well-being.
Kempton *et al.*, 2021	An assessment of health outcomes and methylmercury exposure in unduruku indigenous women of childbearing age and their children under 2 years old	Sawré Muybu Indigenous Land (IL) in the Tapajós River Basin, Brazil.	Cross-sectional study	16 infants under two years old	• Of 16 infants, four (25%) were found to be moderately to severely stunted and only one infant found to be underweight. Anaemia was found in 6 of 12 infants aged 6-24 months. • All infants had not received appropriate vaccination coverage for their age according to health booklets. • Of 16 infants, 3 (18.75%) had H-Hg levels over 6.0 µg/g.
Anticona & Miguel San, 2014	Anaemia and malnutrition in indigenous children and adolescents of the Peruvian Amazon in a context of lead exposure: a cross-sectional study	The Corrientesrive riverside located in the Northeastern Peruvian Amazon, in the Loreto region	Cross-sectional study	236 children and adolescents aged 0-17 years.	• Prevalence of stunting in children aged 0-4 years was 42.1%, underweight 31.6%, and wasting 6.5%. • (+): underweight, age group, and blood lead levels ≥5µ/dL

Table 2. Summary of studies (continued)

Author	*Title*	*Country*	*Design study*	*Sample size*	*Result*
Benefice *et al.*, 2006	Nutritional status of Amerindian children from the Beni River (lowland Bolivia) as related to environmental, maternal and dietary factors	Beni River (lowland Bolivia)	Cross-sectional study	354 children aged 0-10 years old (175 children aged less than 5 years old)	• Prevalence of stunting in children less than 5 years was 41%. • During survey, main alleged cause of children's illness was simple diarrhoea (20%). • This study found 75% children positive for at least one helminth. • After adjusting for age, risk factors for malnutrition (height-for-age) were ethnic group, clinical status, and food diversity.
Yori *et al.*, 2014	Santa Clara de Nanay: the MAL-ED cohort in Peru	Santa Clara de Nanay, Peru	Cohort Study. Data were analysed descriptively.	270 households with children under 5 years	• Prevalence of stunting was 46.3% and 0.2% wasting. • 20.3% of children in the cohort were stunted at 3 months of age; this rose to 38.2% by 12 months, 43.7% by 24 months, and 55.9% by 36 months of age. • Risk factors studied: Access to clean water, improved toilet/sanitation, maternal level of education electricity in household, cooking with fuel, charcoal or wood, wall material from wood, household without concrete or wood floor, roofing material made of thatch, iron, etc.
Roche, Creed-Kanashiro *et al.*, 2011	Infant and young child feeding in the Peruvian Amazon: the need to promote exclusive breastfeeding and nutrient-dense traditional complementary foods	Peru	Descriptive cross-sectional study	32 children aged 0-23 months	• Prevalence of stunting was 39.4%. • Only 12.6% of mothers had stopped breastfeeding before 1 year of age. • Adequate intake of energy and protein from complementary food in comparison with WHO recommendation. • Vitamin A, iron, zinc, and calcium were still inadequate in comparison with WHO recommendations.

Table 2. Summary of studies (continued)

Author	*Title*	*Country*	*Design study*	*Sample size*	*Result*
Muldiasman, *et al.*, 2008	Can early initiation to breastfeeding prevent stunting in 6-59 months old children?	Jambi Province, Indonesia	Cross-sectional study from National Nutrition Survey in Jambi province in 2015	2,502 children aged 6-59 months	• Prevalence of stunting: 27.5% (95% CI: 25.2-29.9) • (+): Early initiation of breastfeeding, birth weight, diarrhoea, house structure, water source, living in rural region, parent's ethnicity and age
Febry *et al.*, 2022	Identification of food diversity factors to overcome stunting in toddlers on the Musi River suburbs, Palembang South Sumatra, Indonesia	South Sumatera, Indonesia	Cross-sectional study	170 children aged 6-59 months	• Only 54.7% households had food diversity for children's diets. • Factors related to food diversity in household were mother's education and food availability. • Factors not related significantly with food diversity were number of family, family's income, livestock ownership, food crop ownership, mass media access, food decision-making, breastfeeding, father's education, and dietary habit.
Islam *et al.*, 2014	Nutritional status of under 5 children belonging to tribal population living in riverine (Char) areas of Dibrugarh district, Assam	Dibrugarh district, Assam, India	Cross-sectional study	500 children under five years	• Prevalence of stunting was 30.4%, underweight 29%, and 21.6% wasting. • Prevalence of stunting was highest in the age group 48-60 months (58.6%), followed by 57.3% in the age group 36-48 months. • (+): gender, socioeconomic class, literacy status of both parents, exclusive breastfeeding, colostrum, age of introducing complementary foods (-): number of family members and pre-lacteal feed given.

(+) Significant risk factor
(-) Insignificant risk factor

Table 3. Research variables related to stunting in children under five years

No	*Research variable*	*No*	*Research variable*	*No*	*Research variable*
1	Age	29	Birth order of child	57	Number of parent's children
2	Gender	30	Type of house floor	58	Feeding frequency
3	Diarrhoea	31	Parent's literacy	59	Mother's illness
4	Water source	32	Source of safe water (pipe/deep well/others)	60	Milk feeding frequency
5	Parent's education	33	Birth weight	61	Mother's income
6	Immunisation	34	House structure	62	Animal kept inside the house
7	Inappropriate complementary feeding practices	35	Living in rural region	63	Language group of head of household
8	Early initiation to breastfeeding	36	Length at birth	64	Hanging utensils after washing
9	Exclusive breastfeeding	37	Cold	65	Handwashing with running water
10	Sanitation	38	Shortness of breath in previous month	66	Use of dry utensils
11	Parent's occupation	39	Quality of water source	67	Water source sharing with animal
12	Age of mother	40	Number of household members	68	Interaction of human-animal.
13	Number of children under 5 years	41	Good physical well-being	69	Receiver of hygiene education
14	Number of people in the household	42	Good emotional well-being	70	Riverine livelihood
15	Parent's ethnicity	43	H-hg level	71	Prelacteal feed given
16	Hand washing with soap	44	Underweight	72	Maternal adiposity
17	Fever	45	Blood lead level	73	Maternal stature
18	Female household head	46	High exposure to oil activity	74	Mother's age at delivery of first child
19	Vitamin A	47	Anaemia	75	Household often hungry
20	Parasite infection	48	Acute respiratory infection	76	Family income
21	Food diversity	49	Household size	77	Type of cooking fuel
22	Socioeconomic class	50	High-carbohydrate foods	78	Type of wall
23	Visiting community base health service	51	High-protein foods	79	Dirty fingers
24	Cough	52	Fats	80	Had slippers/shoes
25	Boiling drinking water	53	Fruits and vegetable	81	Food security status
26	MUAC of mother	54	Suspected measles	82	Breastfeeding
27	Electricity	55	Number of father's children	83	Inadequate nutrition intake
28	Number of mother's children	56	Father lives with another family		

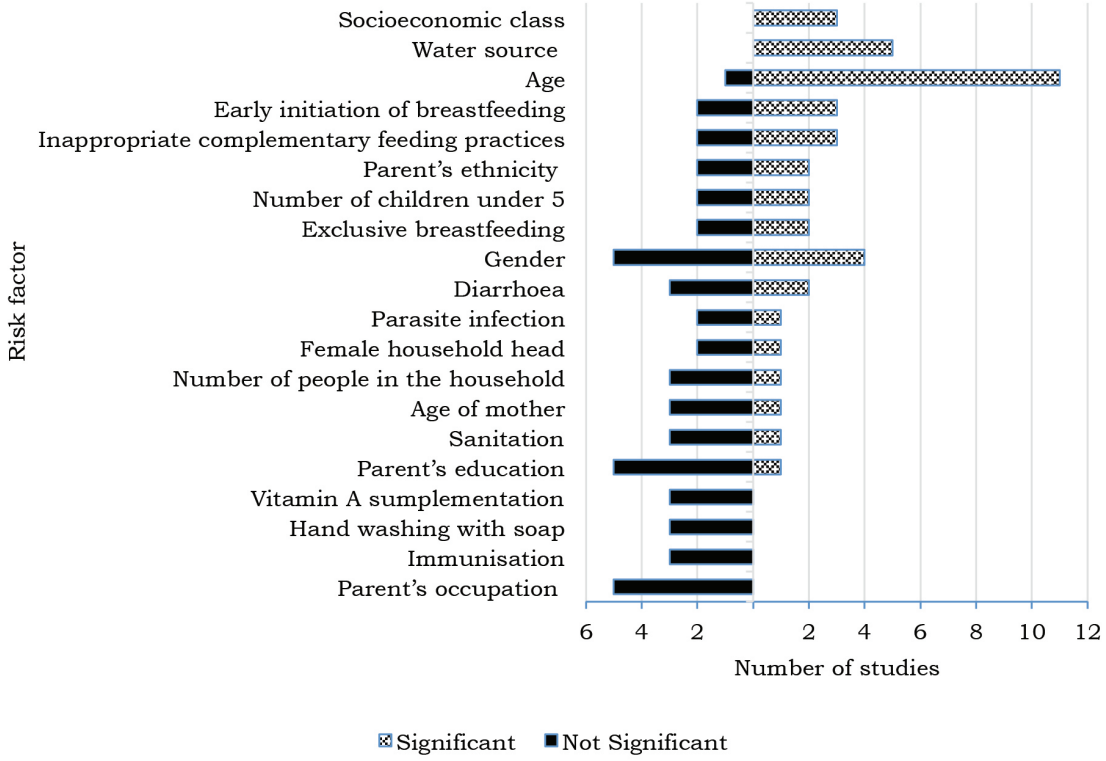

Figure 2. Comparison of risk factor significance

stunting. The majority of studies showed that the age of the child was related to stunting (11 of 12); the older the age of the child, the higher the prevalence of stunting. Parent's occupation, vitamin A supplementation, hand wash, and immunisation have also consistently been shown to be unrelated to stunting. However, apart from parental occupation, these three insignificant variables should be investigated further because they were found in three studies to be significantly related to stunting. Early breastfeeding initiation, inappropriate complementary feeding practices, parent's ethnicity, number of children under the age of five in the household, exclusive breastfeeding, gender, and diarrhoea had all been extensively studied (more than five studies), but the evidence had been inconclusive. The remaining variables were not included in Figure 2, because they were only found in two or fewer studies.

DISCUSSION

Socio-demography

Socio-demography is a study exploring the determinants and consequences of population size, distribution and composition of the demographic process (Murdock, 2019). Referring to the determinants of stunting by WHO, these social and demographic factors are the foundation of various factors that directly cause stunting (WHO, 2014). This study found that the most studied socio-economic-demographic factors related to stunting were age of children, gender, parental education and occupation, parental ethnicity, and socio-economic class. A study on children aged 0-36 months in 179 demographic and health

surveys from 64 low- and middle-income countries (1993-2015) showed a trend of decreasing average HAZ in children with increasing age (Roth *et al*, 2017). This finding is in line with the prevalence of stunting found in other studies in which children aged over 24 months have a greater risk of experiencing stunting than children aged under 24 months (Adhikari *et al.*, 2019; Atlas, 2020; Blankenship *et al.*, 2020; Khan *et al.* 2019; Mengesha *et al.*, 2021; Mutunga *et al.*, 2021; Rajpal *et al.*, 2020; Roba *et al.*, 2021). The risk of stunting between males and females in this study was still inconclusive. The results of the study found that females were more at risk of experiencing stunting in Asia (Khatun *et al*, 2004), and vice versa in research in the African region (Wamani *et al.*, 2007).

Economic vulnerability can occur in communities living in riverside areas. Research from Brazil found that the majority of riverside residents were involved in the agricultural sector, with 65.8% having a family income of up to 1 minimum wage (Rodrigues *et al.*, 2020). Furthermore, in the urban area, households that do not have adequate income will be forced to live near the river. This condition is very likely to form a slum area, which is identical with poor sanitary and drainage. This study found economic status to be consistently correlated with stunting. This finding is considered very important because they are related to the family's ability to meet the nutritional needs of children, prevent infectious diseases, and access a healthy home environment.

Maternal health

Factors of nutritional status and maternal health can lead to stunting in children. In this study, from the aspect of maternal health, the variables found were age of the mother, mid-upper arm circumference (MUAC) of the mother, number of mother's children, mother's illness, maternal adiposity, maternal stature, and mother's age at delivery of the first child. Maternal age was found to be significant in four studies, while the others were only present in one to two studies. Therefore, maternal health still cannot be concluded in this research. Malnutrition during preconception, pregnancy and breastfeeding, mother's short stature, intrauterine growth restriction (IUGR), premature birth, and teenage pregnancy have been shown to be associated with stunting (Beal *et al.*, 2018). Pregnant women require approximately 10-15% more energy than non-pregnant women. A deficiency of energy and protein causes pregnant women to be unable to meet the nutritional needs for foetal growth and development (Achadi *et al.*, 2020; Li *et al.*, 2020).

Short adult women represent a history of suboptimal growth in height, not only due to genetic factors, but also a long history of malnutrition and chronic recurrent infections. This affects organ development. Short pregnant women are at risk of having low birth weight (LBW), small-for-gestational age (SGA), or short babies (Achadi *et al.*, 2020). Several studies have found a strong correlation between mothers who have a short stature and stunting in children (Beal *et al.*, 2018; Li *et al.*, 2020; Oddo *et al.*, 2012; Rachmi *et al.*, 2016; Svefors *et al.*, 2019).

Household condition

Stunting can occur as a result of household conditions. This study found that the variables related to stunting were the number of children under 5 years of age, density of people in the house, electricity, type of house floor, wall, cooking fuel, house structure, high exposure to oil activity, animal kept inside the house, interaction between humans and animals, and hunger and food security status.

Food security refers to the ability of individuals or groups to accomplish access to good, safe and nutritious food. Family food security status is a crucial factor that can affect the nutritional status of family members, especially children under 5 years (Fadzila & Tertiyus, 2019; Helmyati *et al.*, 2019; Raharja *et al.*, 2019; Safitri & Nindya, 2017). The number of family members also plays a role in household food availability. A large number of children and family members will affect the food intake of children in the family (Helmyati *et al.*, 2019; Titaley *et al.*, 2019).

The quality of housing can affect people's health. The various characteristics of housing by the riverside depend on their socio-economic developmental level and cultures. The slum residential areas may be found in urban rivers with low socioeconomic levels. Otherwise, a high-quality living environment can be realised with the support of urban planning and development.

Poor housing is associated with a wide range of health conditions such as respiratory diseases including asthma, cardiovascular diseases, injuries, mental health, and infectious diseases including tuberculosis, influenza, and diarrhoea (WHO, 2018b). The improved housing criteria based on the United Nations are improved drinking water, improved sanitation, sufficient living area, and finished building materials (Tusting *et al.*, 2020).

Water sanitation and hygiene (WaSH)

WaSH can be a determining factor in the incidence of stunting (Cumming & Cairncross, 2016; Helmyati *et al.*, 2019). Inadequate WaSH can result in malnutrition (WHO, 2019). Mechanisms that play a role in the link between WaSH and malnutrition include recurrent diarrhoea, worm infections (soil-transmitted helminths, STH) such as *Ascaris lumbricoides, Trichuris trichiura, Aancylostoma duodenale*, and *Necactor americanus,* and subclinical conditions of the gastrointestinal tract. The exposure to enteric pathogens and symptomatic and asymptomatic infections mediates the impact of WaSH on undernutrition (Budge *et al.*, 2019; Helmyati *et al.*, 2019; WHO, 2019; Zavala, *et al.*, 2021).

Of these three factors, water sources from rivers are consistently associated with stunting. As a result of human activities, both chemical and biological river water pollution can occur. Human activities strongly influence the concentration of faecal coliform. The presence of faecal coliform almost always indicates water contamination by faeces, both human and animal (Bartram & Ballance, 1996). Several studies showed contamination of river water by faecal coliform (Pratama *et al.*, 2020), *Cryptosporidium spp, Giardia spp* (Tandukar *et al.*, 2018), and *Escherichia coli* (Verbyla *et al.*, 2021).

In addition to biological pollution, chemicals originating from industry or mining can pollute river water. We found one study on H-Hg levels in children, which exceeded maximum level (Kempton *et al.*, 2021) and one study on blood lead levels, which correlated with stunting (Anticona & Miguel San, 2014).

Breastfeeding

The most efficient method for ensuring that children receive adequate nutrition is through breastfeeding. Breast milk is believed to benefit infant growth because of its appropriate nutrient composition for children's nutritional requirements (Sirajuddin *et al.*, 2020). Inadequate breastfeeding in the WHO framework related to stunting includes non-exclusive breastfeeding, early initiation of breastfeeding, and weaning (Beal *et al.*, 2018). A study in Indonesia found that stunting occurred outside the age

period of breastfeeding (Sirajuddin *et al.*, 2020). In this study, two of four articles found non-exclusive breastfeeding as a risk factor, but this was still inconclusive.

Dietary intake

Food diversity and the amount of food a child eats per day are significant determinants of stunting and underweight status in children under 5 years of age (Hashmi *et al.*, 2021; Motbainor, Worku & Kumie, 2015). Adequacy of child nutrition includes adequacy of macronutrients and micronutrients; whereby carbohydrates, proteins, and fats fulfil the macronutrient needs (Sudargo, Aristasari & Afifah, 2018). Deficiency of some common micronutrients are vitamin A, zinc, ferum, and iodine (Black *et al.*, 2008), which can affect various aspects of physiology, including immune function and neurodevelopment (Prendergast & Humphrey, 2014).

Inappropriate complementary feeding practices have been extensively studied and showed their potential as a risk factor for stunting. The other variables related to dietary intake were food diversity, high carbohydrate, protein, and fat foods, fruits and vegetables consumption, feeding frequency, and inadequate nutrition intake. They were only found in 1-2 articles; therefore, no conclusion could be drawn from them.

Infection

According to WHO, infectious diseases in children that cause stunting include both clinical and subclinical, namely digestive infections (diarrhoea, environmental enteropathy, and worm parasitic infections), respiratory tract infections, and malaria (Beal *et al.*, 2018). Infectious diseases including diarrhoea, respiratory infections, and fever are associated with stunting in children aged 6–59 months living in urban and rural poor areas (Bardosono, Sastroamidjojo & Lukito, 2007). Additionally, Semba *et al.* (2007) reported that children aged 12-59 months who received complete, partial, or no immunisation had a stunting prevalence of 37%, 47%, and 54%, respectively (Semba *et al.*, 2007). Diarrhoea as a risk factor for stunting was found in five and three articles for parasite/helminth infection. However, both are still inconclusive evidence.

Infectious diseases are highly correlated with the environment. A study found that almost half of the children living by the riverside had experienced diarrhoea in the previous month, with sanitation and water sources as significant risk factors (Susanti, 2019). The other study found that upstream river pollution caused by bathing and sanitary practices explained as many as 7.5% of all diarrhoea-related deaths annually (Garg *et al.*, 2018). Therefore, poor environmental conditions can increase the risk of infectious diseases. Recurrent infections in children will eventually lead to malnutrition, including stunting.

CONCLUSION

The river is a source of life for the communities around it. The prevalence of stunting in children under five years living by the riverside ranged from 20% to 48.3%. Household water sources from rivers and economic status were consistently correlated with stunting. Water sources were an important risk factor for stunting in children living by the riverside. This was not only limited to the use of river water as a source of drinking water, but also for cooking, bathing, sanitary practices, and cleaning food equipment. Although the studied variables aligned with established stunting determinants, further investigation is required to explore the influence of environmental factors and the behaviours of individuals residing by the riverside.

Authors' contributions

Bambang W, Ririn A and Ridha R, conceptualised and designed the study, prepared the draft of the manuscript and reviewed the manuscript; Umar FA, Tri YM, Defriman D and Miko H, reviewed the manuscript.

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Conflict of interest

Authors declare no conflict of interest in this research.

References

Achadi EL, Achadi A, Aninditha T, Thaha AR, Syam AF, Setiarini A & Putra WK (2020). *Pencegahan Stunting Pentingnya Peran 1000 Hari Pertama Kehidupan*. Raja Grafindo, Depok.

Adeniran AA, Mogaji HO, Aladesida AA, Olayiwola IO, Oluwole AS, Abe EM & Ekpo UF (2017). Schistosomiasis, intestinal helminthiasis and nutritional status among preschool-aged children in sub-urban communities of Abeokuta, Southwest, Nigeria. *BMC Res Notes* 10(1):637.

Adhikari RP, Shrestha ML, Acharya A & Upadhaya N (2019). Determinants of stunting among children aged 0–59 months in Nepal: findings from Nepal Demographic and health Survey, 2006, 2011, and 2016. *BMC Nutr* 5(1):1-10.

Alderman H & Headey D (2018). The timing of growth faltering has important implications for observational analyses of the underlying determinants of nutrition outcomes. *PLoS One* 13(4):1-16.

Anticona C, & Miguel San S (2014). Anemia and malnutrition in indigenous children and adolescents of the Peruvian Amazon in a context of lead exposure: a cross-sectional study. *Glob Health Action* 7(1):1-8.

Atlas H (2020). *Prevalence and Correlates of Stunting at Hospital Discharge Among Children 1-59 Months in Western Kenya*. (M.P.H.). University of Washington, Ann Arbor. From https://www.proquest.com/dissertations-theses/prevalence-correlates-stunting-at-hospital/docview/2437772565/se-2?accountid=17242 ProQuest Dissertations & Theses Global database [Retrieved September 20 2022].

Bardosono S, Sastroamidjojo S & Lukito W (2007). Determinants of child malnutrition during the 1999 economic crisis in selected poor areas of Indonesia. *Asia Pac J Clin Nutr* 16(3):512-526.

Bartram J & Ballance R (eds) (1996). *Water Quality Monitoring: A Practical Guide to The Design and Implementation of Freshwater Quality Studies and Monitoring Programmes*. CRC Press, London.

Beal T, Tumilowicz A, Sutrisna A, Izwardy D & Neufeld LM (2018). A review of child stunting determinants in Indonesia. *Matern Child Nutr* 14(4):e12617.

Benefice E, Monroy SL, Jiménez S & López R (2006). Nutritional status of Amerindian children from the Beni River (lowland Bolivia) as related to environmental, maternal and dietary factors. *Public Health Nutr* 9(3):327-335.

Black RE, Allen LH, Bhutta ZA, Caulfield LE, De Onis M & Ezzati M (2008). Maternal and child undernutrition: Global and regional exposures and health consequences. *The Lancet* 371(9608):243-260.

Blankenship JL, Cashin J, Nguyen TT & Ip H (2020). Childhood stunting and wasting in Myanmar: Key drivers and implications for policies and programmes. *Matern Child Nutr* 16(2):e12710.

Budge S, Parker AH, Hutchings PT & Garbutt C (2019). Environmental enteric dysfunction and child stunting. *Nutr Rev* 77(4):240-253.

Cheung YB & Ashorn P (2010). Continuation of linear growth failure and its association with cognitive ability are not dependent on initial length-for-age: a longitudinal study from 6 months to 11 years of age. *Acta Paediatr* 99(11):1719-1723.

Cumming O & Cairncross S (2016). Can water, sanitation and hygiene help eliminate stunting? Current evidence and policy implications. *Matern Child Nutr* 12(S1):91-105.

de Onis M & Branca F (2016). Childhood stunting: a global perspective. *Matern Child Nutr* 12 Suppl 1(Suppl 1):12-26.

Emanuella De Lucia R, Giovanny, F, Carolina V, Gigante DP, Miranda JJ, Yudkin JS & Ong KK (2018). Associations of stunting in early childhood with cardiometabolic risk factors in adulthood. *PLoS One* 13(4):e12617

Fadzila DN & Tertiyus EP (2019). Ketahanan pangan rumah tangga anak stunting usia 6-23 bulan di Wilangan, Kabupaten Nganjuk. *Amerta Nutrition* 3(1):18-23.

Febry F, Ainy A & Sudirman (2022). Identification of food diversity factors to overcome stunting in toddlers on the Musi river suburbs, Palembang South Sumatra, Indonesia. *Jurnal Ilmu Kesehatan Masyarakat* 13(2):224-235.

Fernandes ECB, de Castro TG & Sartorelli DS (2017). Associated factors of malnutrition among African children under five years old, Bom Jesus, Angola. *Rev de Nutr* 30(1):33-44.

Garg T, Hamilton SE, Hochard JP, Kresch EP & Talbot J (2018). (Not so) gently down the stream: River pollution and health in Indonesia. *J Environ Econ Manag* 92:35-53.

Gupta N, Gehri M & Stettler N (2007). Early introduction of water and complementary feeding and nutritional status of children in northern Senegal. *Public Health Nutr* 10(11):1299-1304.

Hashmi S, Safdar NF, Zaheer S & Shafique K (2021). Association between dietary diversity and food insecurity in urban households: A cross-sectional survey of various ethnic populations of Karachi, Pakistan. *Risk Manag Healthc Policy* 14:3025-3035.

Helmyati S, Atmaka DR, Wisnusanti SU & Wiganti M (2019). *STUNTING: Permasalahan dan Tantangannya*. Gadjah Mada University Press, Yogyakarta.

Ikhsan J, Kurniati R & Rozainy M (2021). Analysis of river water quality in the upstream of the Code River, Indonesia. *IOP Conference Series: Earth Environ Sci* 794(1):012044

Islam S, Mahanta TG, Sarma R & Hiranya S (2014). Nutritional status of under 5 children belonging to Tribal population living in Riverine (Char) areas of Dibrugarh district, Assam. *Indian J Community Med* 39(3):169-174.

Kehinde O, Best O, Olerimi S & Ekhoye E (2021). Nutritional status of under five children in the Cameroonian Refugee Settlement in Ogoja, Cross River State, Nigeria. *Int J of Home Sci* 7(1):225-231

Kempton JW, André P, Cristina H, Ana V, Paulo V, de Oliveira M & Basta PC (2021). An assessment of health outcomes and methylmercury exposure in Munduruku indigenous women of childbearing age and their children under 2 years old. *Int J Environ Res Public Health* 18(19):10091.

Khan S, Zaheer S & Safdar NF (2019). Determinants of stunting, underweight and wasting among children < 5 years of age: Evidence from 2012-2013 Pakistan demographic and health survey. *BMC Public Health* 19(1):1-15.

Khatun M, Stenlund H & Hörnell A (2004). BRAC initiative towards promoting gender and social equity in health: A longitudinal study of child growth in Matlab, Bangladesh. *Public Health Nutr* 7(8):1071-1079.

Kinyoki DK, Berkley JA, Moloney GM, Odundo EO, Kandala NB & Noor AM (2016a). Environmental predictors of stunting among children under-five in Somalia: Cross-sectional studies from 2007 to 2010. *BMC Public Health* 16(1):1-9.

Kinyoki DK, Kandala, NB, Manda SO, Krainski ET, Fuglstad GA, Moloney GM & Noor AM (2016b). Assessing comorbidity and correlates of wasting and stunting among children in Somalia using cross-sectional household surveys: 2007 to 2010. *BMJ Open* 6(3):e009854.

Li Z, Kim R, Vollmer S & Subramanian SV (2020). Factors associated with child stunting, wasting, and underweight in 35 low- and middle-income countries. *JAMA Netw Open* 3(4):e203386.

Lissauer T & Carroll W (2021). *Illustrated Textbook of Paediatrics*. Elsevier Health Sciences.

Mengesha A, Hailu S, Birhane M & Belay MM (2021). The prevalence of stunting and associated factors among children under five years of age in Southern Ethiopia: Community based cross-sectional study. *Ann Glob Health* 87(1):111.

Motbainor A, Worku A & Kumie A (2015). Stunting is associated with food diversity while wasting with food insecurity among underfive children in east and west Gojjam zones of Amhara region, Ethiopia. *PLoS One* 10(8):e0133542.

Muldiasman, Kusharisupeni, Laksminingsih E & Besral (2018). Can early initiation to breastfeeding prevent stunting in 6–59 months old children? *J Health Res* 32(5):334-341.

Munn Z, Stern C, Aromataris E, Lockwood C & Jordan Z (2018). What kind of systematic review should I conduct? A proposed typology and guidance for systematic reviewers in the medical and health sciences. *BMC Med Res Methodol* 18(1):1-9.

Murdock SH (2019). *Applied Demography: An Introduction to Basic Concepts, Methods, And Data*. Taylor & Francis, New York.

Mutunga M, Rutishauser-Perera A, Laillou A, Prak S, Berger J, Wieringa FT & Bahwere P (2021). The relationship between wasting and stunting in Cambodian children: Secondary analysis of longitudinal data of children below 24 months of age followed up until the age of 59 months. *PLoS One* 16(11):e0259765-e0259765.

Nguyen PH, Tran LM, Khuong LQ, Young MF, Duong TH, Nguyen HC & Ramakrishnan U (2021). Child linear growth during and after the first 1000 days is positively associated with intellectual functioning and mental health in school-age children in Vietnam. *J Nutr* 151(9):2816-2824.

Oddo VM, Rah JH, Semba RD, Sun K, Akhter N, Sari M & Kraemer K (2012). Predictors of maternal and child double burden of malnutrition in rural Indonesia and Bangladesh. *Am J Clin Nutr* 95(4):951-958.

Olofin I, McDonald CM, Ezzati M, Flaxman S, Black RE & Fawzi WW (2013). Associations of suboptimal growth with all-cause and cause-specific mortality in children under five years: A pooled analysis of ten prospective studies. *PLoS One* 8(5):e64636

Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD & Moher D (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* 372:n71.

Pratama MA, Immanuel YD & Marthanty DR (2020). A multivariate and spatiotemporal analysis of water quality in Code River, Indonesia. *Sci World J* 2020:1-11

Prawirohartono EP & Press, U (2021). *STUNTING: Dari Teori dan Bukti ke Implementasi di Lapangan*. Gadjah Mada University Press, Yogyakarta.

Prendergast AJ & Humphrey JH (2014). The stunting syndrome in developing countries. *Paediatr Int Child Health* 34(4):250-265.

Rachmi CN, Agho KE, Li M & Baur LA (2016). Stunting, underweight and overweight in children aged 2.0–4.9 years in Indonesia: Prevalence trends and associated risk factors. *PLoS One* 11(5):e0154756

Raharja UMP, Waryana SA & Sitasari A (2019). Status ekonomi orang tua dan ketahanan pangan keluarga sebagai faktor risiko stunting pada balita di Desa Bejiharjo. *Ilmu Gizi Indonesia* 3(1):73-82.

Rahmadani RD & Ridlo IA (2020). Perilaku masyarakat dalam pembuangan tinja ke sungai di Kelurahan Rangkah, Surabaya. *Jurnal Promkes: Indonesian J Health Promotion and Health Education* 8(1):87-98.

Rajpal S, Kim R, Joe W & Subramanian SV (2020). Stunting among preschool children in India: Temporal analysis of age-specific wealth inequalities. *Int J Environ Res Public Health* 17(13):4702.

Ricketts TH, Hererra D, Ellis A & Fisher B (2017). Watersheds, forests, and childhood health: Global relationships and policy opportunities. *The Lancet* 389:S17.

Roba AA, Assefa N, Dessie Y, Tolera A, Teji K, Elena H & Fawzi W (2021). Prevalence and determinants of concurrent wasting and stunting and other indicators of malnutrition among children 6-59 months old in Kersa, Ethiopia. *Matern Child Nutr* 17(3):e13172.

Roche ML, Creed-Kanashiro HM, Tuesta I & Kuhnlein HV (2011). Infant and young child feeding in the Peruvian Amazon: the need to promote exclusive breastfeeding and nutrient-dense traditional complementary foods. *Matern Child Nutr* 7(3): 284-294.

Rodrigues Jr, Leite B, Vasconcellos G, Dias LA, Muniz MJ, Espinosa MV & Cabral ER (2020). Socioeconomic and environmental status of riverside communities of Tapajós River, Brazil. E*ur J Public Health* 30(Supplement 5):652.

Roth DE, Krishna A, Leung M, Shi J, Bassani DG & Barros AJD (2017). Early childhood linear growth faltering in low-income and middle-income countries as a whole-population condition: analysis of 179 Demographic and Health Surveys from 64 countries (1993-2015). *Lancet Glob Health* 5(12):e1249-e1257.

Rukambile E, Muscatello G, Sintchenko V, Thomson PC, Maulaga W, Mmassy R & Alders R (2020). Determinants of diarrhoeal diseases and height-for-age Z-scores in children under five years of age in rural central Tanzania. *J Prev Med Hyg* 61(3):e409-e423.

Safitri CA & Nindya TS (2017). Hubungan ketahanan pangan dan penyakit diare dengan stunting pada balita 13-48 bulan di Kelurahan Manyar Sabrangan, Surabaya. *Amerta Nutrition* 1(2):52-61.

Sanchez JF, Halsey ES, Bayer AM, Beltran M, Razuri HR, Velasquez DE & Lescano AG (2015). Needs, acceptability, and value of humanitarian medical assistance in remote Peruvian Amazon riverine communities. *Am J Trop Med Hyg* 92(6):1090-1099.

Semba RD, De Pee S, Berger SG, Martini E, Ricks MO & Bloem MW (2007). Malnutrition and infectious disease morbidity among children missed by the childhood immunisation program in Indonesia. *Southeast Asian J Trop Med Public Health* 38(1):120-129.

Shinta H, Utami PJ & Adiwijaya S (2020). Potential stunting in riverside peoples (Study on Pahandut Urban Village, Palangka Raya City). *Bp Int Res Critic Inst J (BIRCI-Journal)* 3(3):1618-1625.

Sirajuddin, Asbar R, Nursalim & Tamrin A (2020). Breastfeeding practices can potential to prevent stunting for poor family. *Enferm Clín* 30:13-17.

Stevens GA, Finucane MM & Paciorek CJ (2016). Levels and Trends in Low Height-for-Age. In Black RE, Laxminarayan R, Temmerman M *et al.* (eds). *Disease Control Priorities*, *Third Edition (Volume 2): Reproductive, Maternal, Newborn, and Child Health* (pp. 85-93). The World Bank, Washington DC

Sudargo T, Aristasari T & Afifah A. (2018). *1000 Hari Pertama Kehidupan.* Gadjah Mada University Press, Yogyakarta.

Sulaiman AA, Bushara SO, Elmadhoun WM, Noor SK, Abdelkarim, M, Aldeen IN & Ahmed MH (2018). Prevalence and determinants of undernutrition among children under 5-year-old in rural areas: A cross-sectional survey in North Sudan. *J Family Med Prim Care* 7(1):104-110.

Susanti E (2019). Risk factors for diarrhea cases in communities living along Deli River, North Sumatera. *J Epidemiology Public Health* 4(1):47-54.

Svefors P, Sysoev O, Ekstrom EC, Lars Ake P, Arifeen SE, Naved RT & Selling K (2019). Relative importance of prenatal and postnatal determinants of stunting: data mining approaches to the MINIMat cohort, Bangladesh. *BMJ Open* 9(8): e025154

Tandukar S, Sherchand JB, Bhandari D, Sherchan SP, Malla B, Ghaju Shrestha R & Haramoto E (2018). Presence of Human Enteric Viruses, Protozoa, and Indicators of Pathogens in the Bagmati River, Nepal. *Pathogens* 7(2):38.

Titaley CR, Ariawan I, Hapsari D, Muasyaroh A & Dibley MJ (2019). Determinants of the stunting of children under two years old in Indonesia: A multilevel analysis of the 2013 Indonesia Basic Health Survey. *Nutrients* 11(5):1106.

Tusting LS, Gething PW, Gibson HS, Greenwood B, Knudsen J, Lindsay SW & Bhatt S (2020). Housing and child health in sub-Saharan Africa: A cross-sectional analysis. *PLOS Medicine* 17(3):e1003055.

Udoh EE & Amodu OK (2016). Complementary feeding practices among mothers and nutritional status of infants in Akpabuyo Area, Cross River State Nigeria. *Springerplus* 5(1):1-19.

Verbyla ME, Calderon JS, Flanigan S, Garcia M, Gersberg R, Kinoshita AM & Welsh M (2021). An assessment of ambient water quality and challenges with access to water and sanitation services for individuals experiencing homelessness in riverine encampments. *Environ Eng Sci* 38(5):389-401.

Victora CG, Adair L, Fall C. Hallal PC, Martorell R, Richter L & Sachdev HS (2008). Maternal and child undernutrition: consequences for adult health and human capital. *The Lancet* 371(9609):340-357.

Victora CG, De Onis M, Hallal PC, Blössner M & Shrimpton R (2010). Worldwide timing of growth faltering: revisiting implications for interventions. *Pediatrics* 125(3):e473-e480.

Vonaesch P, Randremanana R, Gody JC, Collard, JM, Giles-Vernick T, Doria M & Andriatahirintsoa EJ (2018). Identifying the etiology and pathophysiology underlying stunting and environmental enteropathy: Study protocol of the AFRIBIOTA project. *BMC Pediatrics* 18(1):1-18.

Wachukwu-Chikodi H & Sonye C (2022). Assessment of complementary feeding practices and nutritional status of children (0-24 months) in Akuku Toru local government area of Rivers State, Nigeria. *Asian Food Sci J* 27(7):24-34.

Wamani H, Åstrøm AN, Peterson S, Tumwine JK & Tylleskär T (2007). Boys are more stunted than girls in Sub-Saharan Africa: A meta-analysis of 16 demographic and health surveys. *BMC pediatrics* 7(1):17.

WHO (2014). *Global nutrition targets 2025: Stunting policy brief*. WHO Press, Geneva.

WHO (2018a). *Reducing stunting in children: equity considerations for achieving the Global Nutrition Targets 2025.* WHO Press, Geneva.

WHO (2018b). *WHO housing and health guideline.* WHO Press, Geneva.

WHO (2019). *Water, sanitation, hygiene and health: a primer for health professionals.* WHO Press, Geneva.

Yori PP, Lee G, Olórtegui MP, Chávez CB, Flores JT, Vasquez AO & Kosek M (2014). Santa Clara de Nanay: The MAL-ED cohort in Peru. *Clin Infect Dis* 59(4):S310-316.

Zahtamal Z, Chandra F, Restila R & Restuastuti T (2020). Defecation behaviour in elementary school age children who live along the Kampar River Riau Province. *Jurnal Kesehatan Lingkungan* 12(2):87-96.

Zavala E, King SE, Sawadogo-Lewis T & Roberton T (2021). Leveraging water, sanitation and hygiene for nutrition in low-and middle-income countries: A conceptual framework. *Matern Child Nutr* 17(3):e13202.