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Review Article

Effect of Fish-Based Diet on Malnourished Children: A Systematic Review

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Abstract

Background: Malnutrition in children is mainly caused by the lack of protein and fat intake which harms their ability to grow and survive. Accurate data on the benefits of fish-based foods on the nutritional status of children is limited. The present systematic review aimed to provide an overview of published articles on the nutritional value of fish-based foods for children.

Methods: A systematic review was performed during 2000-2021 by searching Science Direct, Cochrane Library, PubMed, ProQuest, and Wiley Online Library databases. The full text of selected articles in English was screened based on the inclusion and exclusion criteria. Included articles were all experimental studies (randomized control trial, quasi-randomized trial) or mixed methods studies involving malnourished children. The study was reported under the preferred reporting items for systematic reviews and meta-analyses guidelines. The risk of bias was assessed using the Cochrane tool.

Results: A total of 330,859 articles were screened, out of which eight articles were included in the systematic review. Interventions included fish-based foods and beverages such as wafer bars, Jemawut-tuna cookies, Amizate in chocolate drink, dried fish powder, flaxseed oil supplemented with fish oil capsules, and porridge fortified with fish powder. Primary or secondary outcomes were the determination of zinc level, height growth, erythrocyte n-3 polyunsaturated fatty acid content, safety and acceptability, intestinal integrity, and cognitive development. The results showed that dried fish powder produced the most significant effect on body weight.

Conclusion: The consumption of dried fish powder had positive effects on the recovery of malnourished children.

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Keywords ● Fish flour ● Body weight ● Malnutrition ● Child

What's Known

- Malnutrition is common in children, specially in developing countries. Growth and developmental disorders in children are associated with protein intake below recommended dietary allowance.
- Fish is a good source of nutrients, such as primary macronutrients (protein, fat) and micronutrients (vitamins, minerals). Fish-based diet improves nutritional status during early childhood.

What's New

- Fish-based foods are produced in various forms, not only to preserve nutritional value but also to make fish consumption attractive to children.
- Dried fish powder effectively provides nutrients and improves children's nutritional status. Fish fortified with other ingredients is more effective and the preferred choice to enhance children's health.

Introduction

Adequacy of nutrition is an important issue in every country as it closely relates to national development. It mainly involves young children affecting their cognitive development, education, personality traits, and future productivity.[1-3] Improper feeding practices during infancy and early childhood lead to nutritional deficiencies with the result that they often suffer from infections and intestinal disorders, which in turn impair optimal growth and development.[4] Fish-based foods have been proven to be effective in improving the quality of nutrition in early childhood.[5, 6] Fish contains primary macronutrients (protein and fat) and micronutrients (vitamins and minerals), and therefore greatly contributes to food security and global nutrition.[3] In developing countries, fish is the main source (75%) of daily animal protein and complementary foods.[7, 8] For example, in Egypt, fish is the main source of animal protein and is popular among the low- and middle-income class, since it is readily available and affordable.[9] Nowadays, fish farming has become a sustainable source of high-quality protein foods.[10, 11]

Inadequate protein intake is closely related to impaired growth and development in children. Physiologically, protein plays an important role in supporting all processes in the human body.[12] Therefore, malnutrition can cause serious health problems and must be addressed immediately. Globally, around 47 million children are stunted, mainly in low- and middle-income countries. In addition, malnutrition and stunted growth are associated with deficiencies in vitamin A, iron, and iodine,[13] which are characterized by blindness, impaired learning, failure to thrive, increased physical weakness, and mortality.[8] Several studies showed that malnutrition is a major risk factor for disease and death in children in Kenya, Uganda, Malawi, Zimbabwe, and Zambia.[14-18] A common factor in these countries is poor economic conditions leading to shortages of nutritious food, such as fish. However, in these countries, aquaculture has great potential to increase access to fish to address food shortages, reduce malnutrition, and improve the nutritional status of children.[11]

Various studies have demonstrated the beneficial effects of fish consumption on body functions as well as the importance of adequate protein intake by children at different stages of their development to adulthood.[19-21] However, the effect of fish consumption on malnutrition has not been fully addressed. To effectively promote community health, the present study aimed to review various published articles on the effects of fish-based diets on malnourished children.

Materials and Methods

A systematic review was conducted on studies published in English between January 2000 to December 2021. A complete search was performed in PubMed, Science Direct, ProQuest, Wiley's online library, and Cochrane Library. The sources were managed using Mendeley reference management software 1.19.8 (Elsevier, Amsterdam, Netherlands) to remove duplications. Based on the specific syntax of various databases, keywords, and phrases (MeSH) including fish flour, malnutrition, and child were used for the search, e.g., Fish flour [Title/Abstract] OR Fish product [Title/Abstract] OR Fish meal [Title/Abstract]) AND Malnutrition [Title/Abstract] OR Malnourishment [Title/Abstract] OR Undernutrition [Title/Abstract].

The inclusion criteria were studies that used fish-based ingredients in any form, assessed body weight, body mass index (BMI), and anthropometric measurement outcomes (both primary and secondary outcomes), and compared the effectiveness of fish-based foods/drinks with other ingredients. The exclusion criteria were studies in adults and pregnant women, food that is not based on fish as the main product, non-English articles, and articles in the form of case reports, reviews, books, and commentaries. PICOS framework (population, intervention, comparison, outcomes, and study) was used to formulate the eligibility criteria (table 1).

The authors (PL, MA) independently reviewed the articles, and disagreements were resolved by another reviewer. The full text of the articles (objectives, methodology, results, and conclusion) was screened based on the inclusion and exclusion criteria. In addition, the reference lists of selected articles were manually reviewed by the first author to extract additional relevant articles. Included articles were all experimental studies (randomized control trial, quasi-randomized trial) or mixed methods studies involving malnourished children.

This study was reported under the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[22] The extracted information was evaluated using the GRADE (grading of recommendations, assessment, development, and evaluation) framework, and the associated risk of bias was rated as very low, low, moderate, and high.[23, 24]

Table 1: PICOS (population, intervention, comparison, outcomes, and study) framework used to formulate eligibility criteria for the articles

Items	Statement
Problem	Undernutrition in children
Intervention	Fish-based food
Comparison	Source of food from plants or other animals
Outcome	Anthropometric indices
Study design	Randomized controlled trial, quasi-randomized trial, or mixed methods

Results

A total of 330,859 articles were initially selected, 32,650 through PubMed, 6,243 through Science Direct, 263,707 through ProQuest, 26,611 through Cochrane Library, and 1,648 through Wiley Online Library. Due to various reasons, 330,850 records were excluded, and finally, eight articles were included in the systematic review (figure 1).

Overview of the Included Studies

The studies were conducted in Asia (Cambodia: 2, Indonesia: 1, and India: 1) and Africa (Zambia: 1, Kenya: 1, Gambia: 1, and Malawi: 1). All studies were intervention-based, involving fish as a basic ingredient fortified with other nutrients such as vegetables, fruit, and spices. The participants were children (n=438) aged from three months to seven years who suffered from moderate acute malnutrition (MAM) or severe acute malnutrition (SAM). A summary of the reviewed studies is presented in table 2.

Fish-based Food Intervention

The types of food used for interventions included cylindrical wafer bars with pure fish paste,[25, 32] Jemawut-tuna cookies,[26] Amizate in chocolate drink,[27] dried fish powder (locally called chisense),[28] flaxseed oil containing ready-to-use therapy food (RUTF) with additional fish oil capsules (FFO-RUTF),[29] purified fish oil,[30] and porridge fortified with fish powder.[31] The intervention period varied from 1 month to 1 year. Some studies provided parental nutritional education.[25, 26, 29]

Outcomes

The primary or secondary outcome variables were zinc levels,[26] height growth,[27-32] erythrocyte n-3 polyunsaturated fatty acid (PUFA) content,[29] safety and acceptability,[29] intestinal integrity,[30] and cognitive development.[30]

Effect of Fish-based Nutritional Intervention on Children's Growth

The effect of interventions on malnourished children varied in different countries. While some studies reported a significant effect from the interventions, others reported no statistically significant results. In a study on malnourished children in Cambodia, the intervention involved the use of RUTF in the form of wafer bars for two months and no significant improvements were observed (P>0.05).[25] Another study in Kenya also reported no significant effect of the intervention on the index of linear growth.[29] Similarly, the use of freshwater fish with soy, mung beans, and coconut did not show any improvements in anthropometric indices.[32] On the other hand, some studies reported significant improvements in the parameters of malnutrition. A study in Indonesia used Jemawut-tuna cookies and reported a significant improvement in nutritional status after the intervention (P<0.001).[26]

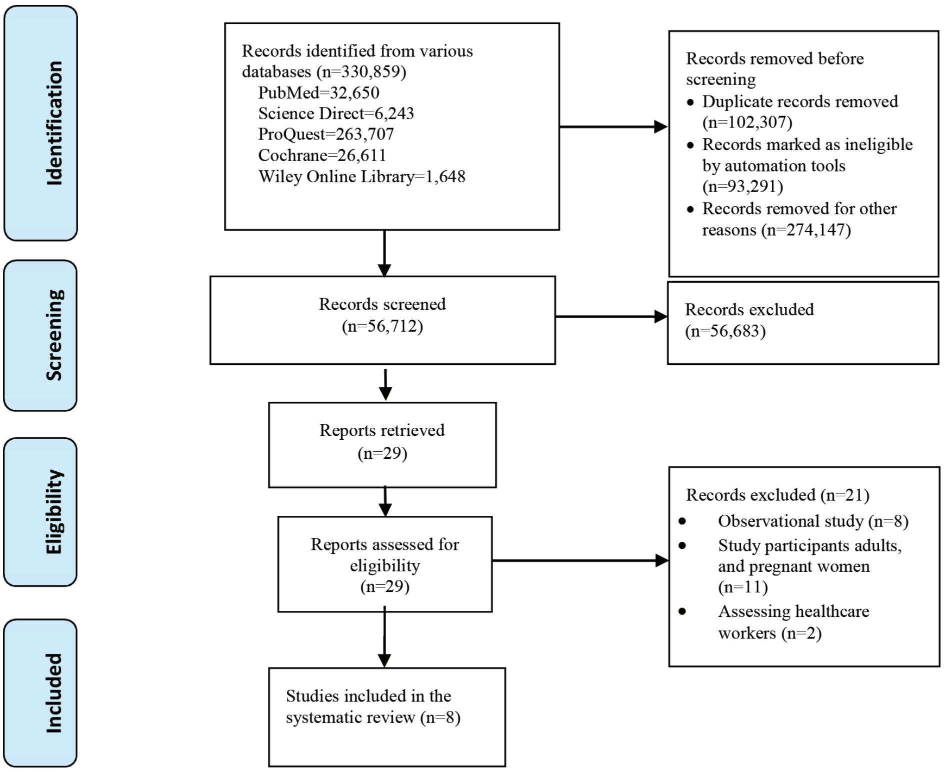

Figure 1: The flow diagram shows the study selection strategies according to PRISMA guidelines.

Table 2: A summary of the studies selected for review

Articles	Objectives	Study design	Participants	Intervention	Evaluations	Outcome	Quality
Sigh et al., 2018, Cambodia[25]	Weight gain	RCT	121 children aged 6-59 months with SAM. Randomly divided into two groups: Control (n=61) treatment with BP-100™ and intervention (n=60) treatment with NumTrey.	The intervention duration was eight consecutive weeks, with follow-up visits every two weeks. Patients aged 6-11 months: Minimum consumption of either 1 wafer with pure fish-based paste (NumTrey) or 1/3 bar (BP-100™). Patients aged 12-23, 24-35, and 36-59 months: A minimum consumption of 1.5 wafers or 1/3 bar, 2 wafers or 2/3 bar, and 3 wafers or 2/3 bar, respectively. Enough to pass the appetite test.	Weight was measured in light clothes (no diapers) to the nearest 100 g. MUAC was measured to the nearest 1 mm (left arm). Bilateral pitting edema was assessed by pressing a finger for 8-10 sec on the foot, hand, and forearm.	There was no statistically significant difference between the two RUTFs (0.02 g/Kg/day, 95% CI: 0.49-0.46). The difference between the two RUTFs was not statistically significant ($P>0.05$, difference=0.06 g/Kg/day, 95% CI: 0.41-0.54).	High
Ikawati et al., 2020, Indonesia[26]	Weight gain, zinc level	Pre- and post-interven-tion study	48 malnourished children aged 6-24 months. Divided into two groups: Control (n=24) given a biscuit provided by the Ministry of Health and intervention (n=24) given foxtail millet-tuna cookies.	60 days intervention and additional eight sessions of nutritional education.	Weight measurement (not described).	There was a significant difference in nutritional status (weight/age) intake between the intervention and control groups ($P<0.001$).	Low
Nesse et al., 2014, India[27]	Height, weight, and BMI	RCT	438 malnourished children aged 6-8 years (227 boys and 211 girls) from six government schools	The children were randomized to receive one of the following three interventions for 120 days: (i) a chocolate drink consisting of 60 g of cocoa powder in 120 mL drinking water (placebo), (ii) a chocolate drink containing 3 g/day of Amizate, (iii) a chocolate drink containing 6 g/day of Amizate.	Height, weight, and BMI were measured during each visit.	There was a significant increase in body weight between baseline and four months after the intervention ($P<0.05$).	Moderate
Chipili et al., 2022, Zambia[28]	Linear growth	RCT	186 infants aged 6-7 months Divided into two groups: Intervention (n=100) and control (n=86).	Infants in the intervention group received 12 g of dried fish (chisense) powder per day, while infants in the control group received 7 g of sorghum powder per day to provide the same energy intake.	Mothers were given a time and day in a month to bring the infant for weight and length measurements.	A significant intervention effect was found between the fish and sorghum groups for WAZ ($P<0.05$) The addition of fish powder during early complementary feeding improved the infant's linear growth outcome.	High

Articles	Objectives	Study design	Participants	Intervention	Evaluations	Outcome	Quality
Jones et al., 2015, Kenya[29]	Erythrocyte n-3 PUFA content, linear growth, safety, and acceptability	RCT	60 children aged 6 to 50 months with SAM	Standard or flaxseed oil containing RUTF was given to children at a weight-based dose until MUAC was >11.5 cm, weight-for-height/length z-score >-3, or edema had resolved (depending on enrollment criteria) at two consecutive weekly visits. Parents were advised not to give any other food apart from breast milk.	Gas chromatography. Insulin-like growth factor-1 (IGF-1) provided an index of linear growth potential. Anthropometric indices.	There was no difference in IGF-1 between the arms at any time point, but all arms had a highly significant increase in IGF-1 by day 28 compared to baseline, which was sustained to day 84.	High
Van der Merwe et al., 2013, Gambia[30]	Intestinal integrity, growth, and development	RCT	172 infants aged 3-9 months	Supplementation started at three months of age and ended at nine months of age when all outcome measurements were taken apart from cognitive function (assessed at 12 months of age). The intervention group received 2 mL of highly purified fish oil, which supplied 200 mg DHA and 300 mg EPA/d. The control group was given the same volume of olive oil.	Anthropometric measurements. Infant lengths and weights.	Statistically significantly larger MUAC (effect size: 0.31 z-score, 95% CI: 0.06-0.56, P=0.017)	High
Lin et al., 2008, Malawi[31]	Weight gain and height growth during Infancy	Prospective RCT	240 children aged 6-12 months	Mothers of children receiving FP were shown a pre-prepared sample of porridge to demonstrate the appropriate consistency. Each mother then received identical cups and teaspoons and was shown how far to fill the cup to make 1 serving of porridge (70 g). Each mother also received a supply of powdered fish and was shown how many teaspoons (2.5) were to be mixed into the porridge.	Anthropometric indices were calculated using the WHO 2005 standards.	Children who received FS gained more weight than children who received FP from 6-12 months of age, but not from 12-18 months of age (P<0.61).	High
Borg et al., 2020, Cambodia[32]	WAZ, HAZ, WHZ, MUAC	RCT	292 Infants aged 6-11 months	RUSF uses local ingredients, including small freshwater fish, soy, mung beans, and coconut. 40-110 g of RUSF per day, depending on the child's age for six months.	Anthropometric measurements included weight to the nearest 0.1 Kg, recumbent length to the nearest 0.1 cm, and MUAC to the nearest 1 mm.	No statistically significant differences between the groups for any of the anthropometric changes. Mean height increased between 6.4-6.7 cm in all groups. Mean weight increased between 1.20-1.30 Kg in all groups.	High

RCT: Randomized controlled trial; SAM: Severe acute malnutrition; MUAC: Mid-upper arm circumference; RUTF: Ready-to-use therapeutic food; FP: Fish-fortified thickened maize porridge; FS: Fortified spreads; RUSF: Ready-to-use supplementary food; CI: Confidence interval; BMI: Body mass index; WAZ: Weight-for-age z-score; HAZ: Height-for-Age Z-Score; WHZ: Weight-for-height z-score; PUFA: Polyunsaturated fatty acid; DHA: Docosahexaenoic acid; WHO: World Health Organization

However, we rated that study as low-quality with a high risk of bias. Nesse and colleagues used chocolate drinks containing fish protein hydrolysate and reported a significant increase in body weight between baseline and four months post-intervention (P<0.05).[27] In Zambia, the use of chisense significantly increased the body weight of malnourished children (P<0.05).[28] The study in Gambia used purified fish oil and reported a significant increase in mid-upper-arm circumference (MUAC) (P=0.017).[30]

Quality Assessment and Risk of Bias

Quality assessment of the studies, using the GRADE framework, showed that the study by Ikawati and colleagues (Indonesia)[26] was of low quality, and the study by Nesse and colleagues (India)[27] was of moderate quality (table 3). The risk of bias assessment showed that the study by Ikawati and colleagues had a high risk of bias due to the lack of sufficient information related to outcome assessment and lack of randomization accuracy.[26] Three other studies[27, 28, 30] showed one or more areas of some concern (figure 2).

Discussion

Various studies have reported that fish-based foods can address malnutrition in children, specially in low- and middle-income countries. Among all types of fish-based foods, the results showed that dried fish powder produced the most significant effect. A previous study also found that dried fish played an important role in the diet and nutrition of people in Bangladesh.[33] It was reported that fish is a potential source of animal protein that positively affects the growth of infants and children. Its protein content is

Table 3: Summary of the risk of bias assessment for eligible studies

Article	Randomization process	Deviations from the intended intervention	Missing outcome data	Measurement of the outcome	Selection of the reported results	Overall
Sigh et al.[25]	Low	Low	Low	Low	Low	Low
Ikawati et al.[26]	Some concerns	Low	Low	No information	High	High
Nesse et al.[27]	Low	Low	Some concerns	Low	Some concerns	Some concerns
Chipili et al.[28]	Low	Low	Some concerns	Low	Low	Some concerns
Jones et al.[29]	Low	Low	Low	Low	Low	Low
Van der Merwe et al.[30]	Low	Low	Some concerns	Low	Low	Some concerns
Lin et al.[31]	Low	Low	Low	Low	Low	Low
Borg et al.[32]	Low	Low	Low	Low	Low	Low

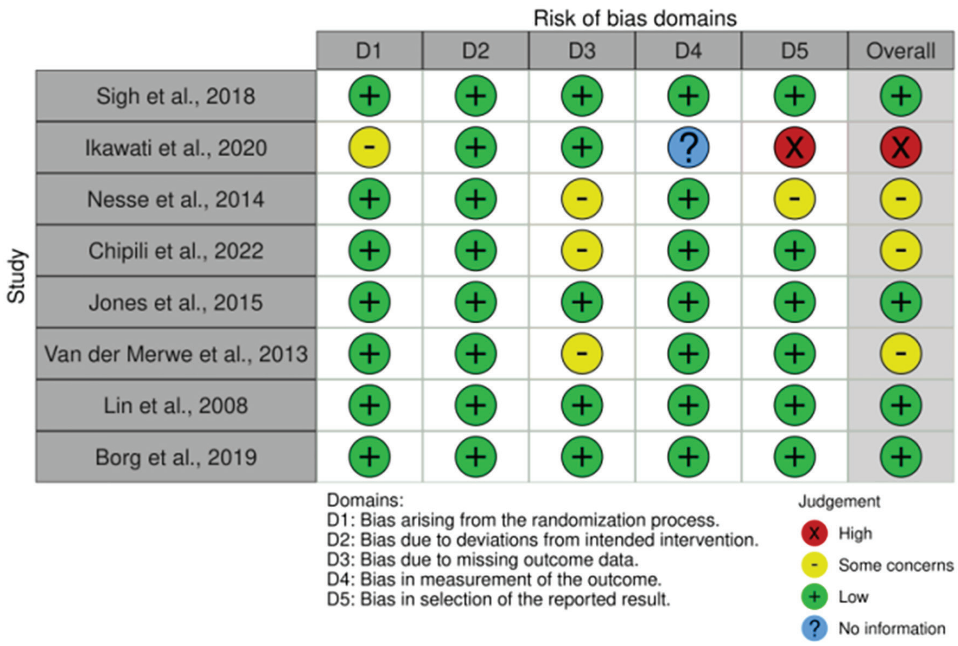

Figure 2: Assessment of the risk of bias of the eligible studies using the five domains in a traffic light plot.

equivalent to beef, chicken, eggs, or liver, while it is cheaper and more affordable for low-income families.[34] Due to n-3 PUFA content, a fish-based diet is important for infants and children to improve their growth. In addition, the proteins and peptides from fish have a high nutritional value and are beneficial for general health. Fish is also a great source of micronutrients, such as vitamins and minerals.[35] While fish is readily accessible in many countries, it can be an expensive and unaffordable food item in some other countries.[36, 37] In the present review study, we mainly focused on the low- to middle-income countries, but did not take into account their financial ability to purchase nutritious food such as fish. Nonetheless, we believe that there are other types of fish-based foods that all people can access and afford.

Of the included articles, two studies reported no statistically significant difference in anthropometric indices (*e.g.*, body weight) after the interventions.[25, 32] The main reasons were stated as low rehabilitation from acute malnutrition in the outpatient treatment of SAM and difference in compliance by patients (*i.e.*, whether the RUTF had been actually consumed, shared with other people, sold, or lost).[25] Borg and colleagues concluded that the reason was due to the low BMI of the mothers during pregnancy.[32] Other studies also confirmed the effect of low BMI during pregnancy on malnutrition in children.[38-41]

Most of the included studies reported a significant effect on anthropometric parameters after intervention with fish-based foods and beverages. Amizate is a fish protein hydrolysate (FPH).[27] FPH is the result of the biological or chemical decomposition of protein derived from fish into its simplest form. In hydrolyzed form, this protein is easily digested and absorbed to enhance the availability of the plasma amino acids.[42-44] FPH from various types of fish has been produced using papain.[45-47]

In other forms of fish-based food, fish oil supplementation has no significant effect on anthropometry, specially the body weight of infants at the age of nine months. However, the positive effect on body weight was observed when they became 12 months of age.[30] This could be due to the slow effect of fish oil on body fat (as indicated by MUAC), which increases skin thickness at the age of 12 months rather than nine months.[45, 48, 49]

The main limitation of the study is a specific focus on published articles from low- to middle-income countries, which undermines the generalizability of our findings. In addition, our findings were negatively affected by the financial capability of the families to purchase nutritious food.

Conclusion

Most of the included studies found that dried fish powder had positive effects on the recovery of malnourished children. In general, fish-based foods had positive effects on malnourished children, and there was no statistically significant difference in its form of production.

Acknowledgment

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Authors' Contribution

L.B: Study design; P.L, M.A.A: Database search, screening articles, data extraction; L.B, P.L: Risk of bias assessment; M.A.A: Data presentation. All authors have contributed to the writing and revising of the manuscript. They have read and approved the final manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflict of Interest: None declared.

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