|  |  |
| --- | --- |
| **Ministry of Education and Training** | **Ministry of Health** |

**National Institute of Nutrition**



**PHAN TIEN HOANG**

**Assessment of Nutritional Status and the results of Iron and Zinc supplementation in Children aged 1-3 years with Low Nutritional Status in Some Northern Provinces (2017 – 2020)**

**Specialization: Nutrition**

**Code: 9720401**

**SUMMARY OF DOCTORAL DISSERTATION**

Ha Noi - 2023

**THIS WORK WAS COMPLETED AT**

**INSTITUTE OF NUTRITION**

**Scientific guides:**

1. **Associate Dr. NGUYEN QUANG DUNG**
2. **Associate Dr. TRAN THUY NGA**

**Reviewer 1:**

**Reviewer 2:**

**Reviewer 3:**

**The thesis will be defended at the Institute-level doctoral thesis grading committee at the National Institute of Nutrition**

**At the hour, day, month, year**

**The thesis can be found at:**

* **National Library**
* **Institute of Nutrition Library**

LIST OF WORKS

RELATED TO THE PUBLISHED THESIS

1. Phan Tien Hoang, Nguyen Thi Lan Phuong, Tran Thuy Nga, Le Danh tuyen, Nguyen Quang Dung (2019). Prevalence of underweight, anemia, iron deficiency, and zinc deficiency in 1-3-year-old children with severe acute malnutrition. Journal of Nutrition and Food, Volume 15, Issue 4 - 2019, Pages 1-10.

2. Phan Tien Hoang, Nguyen Quang Dung, Nguyen Thi Lan Phuong, Tran Thuy Nga, Le Danh Tuyen (2022). The effectiveness of combined iron and zinc supplementation on anemia, iron deficiency, and zinc deficiency in 1-3-year-old children with severe acute malnutrition. Journal of Nutrition and Food, Volume 18, Issue 1 - 2022, Pages 30-37.

**INTRODUCTION**

Malnutrition and nutrient deficiencies are common public health issues in developing countries. Growth faltering in children, with severe acute malnutrition being one of the global public health challenges. Nutrient deficiencies are the direct or indirect cause of over 50% of all deaths in children under 5 years of age worldwide. Approximately 12% of deaths in children under 5 years old are caused by four common nutrient deficiencies, including iron, iodine, vitamin A, and zinc. Iron and zinc deficiencies are among the most common micronutrient deficiencies globally, with women and children, especially those under 5 years of age, being at particular risk of nutrient deficiencies. The prevalence of iron deficiency in children aged 6 to 59 months is 53.2% nationwide. The prevalence of zinc deficiency in children aged 6-59 months is 58.0%. Compared to the nationwide survey in 2015, the prevalence of zinc deficiency in children aged 6-59 months has significantly decreased (from 69% to 58.0%). Iron and zinc deficiencies are common in rural and mountainous areas among children aged 6-59 months.

Assessing the effectiveness of separate iron or zinc supplementation on the status of the other micronutrient (e.g., zinc on iron status and iron on zinc status) or combined iron and zinc supplementation can help us better understand the negative effects (adverse effects) related to increasing supplementation dose 1-2 times higher than the recommended intake. Therefore, more information is needed from interaction studies of iron and zinc supplementation or enhanced combined iron and zinc on growth and micronutrient status.

Researching and finding appropriate solutions for supplementing essential nutrients is crucial for preventing iron and zinc deficiencies, especially in malnourished children under 5 years old. Therefore, we conducted a study entitled "*Assessing the Nutritional Status and Results of Iron and Zinc Supplementation in Malnourished Children Aged 1-3 in Some Northern Provinces (2017-2020)*." We aimed to gain more knowledge about iron and zinc and provide evidence on the effects of supplementing them separately or together on nutritional status and nutrient levels in malnourished children aged 1-3.

**Research objectives:**

* Describe the prevalence of underweight, stunting, anemia, iron deficiency, and zinc deficiency in malnourished children aged 1-3 in some communes of Ha Nam, Vinh Phuc, and Phu Tho provinces in 2017.
* Evaluate the results of reducing the prevalence of malnutrition, anemia, iron deficiency, and zinc deficiency in malnourished children aged 1-3 after 6 months of intervention in the group supplemented with zinc or the group supplemented with iron and zinc.

**New contributions of the thesis**

The research results of the topic provide evidence of the status of underweight, stunting, anemia, iron deficiency, and zinc deficiency in malnourished 1-3 year-old children. From there, solutions for intervention and prevention of malnutrition and nutrient deficiencies are proposed for stunted children in general and malnourished 1-3 year-old children in particular in economically difficult rural and mountainous areas.

The research results of the topic suggest that supplementing zinc alone or combined with iron in a 1:1 ratio and a concentration of 15mg of iron + 15mg of zinc is effective in intervening and preventing malnutrition and nutrient deficiencies in malnourished 1-3 year-old children in some rural and mountainous areas. Through this research, we can compare the results of supplementing zinc alone or the iron and zinc combination on stunted children. The topic's results also open up a research direction for supplementing nutrients at a higher concentration on children of older age groups, while providing evidence to recommend the supplementation of iron and zinc in the solutions for intervention and prevention of malnutrition and nutrient deficiencies.

**Thesis contributions:**

The thesis is structured into 180 pages, including the following sections: Introduction (2 pages); Chapter 1 - Literature Review (41 pages); Chapter 2 - Objectives and Methods (20 pages); Chapter 3 - Research Results (30 pages); Chapter 4 - Discussion (20 pages); Conclusion (28 pages); Recommendations (1 page); References (171 sources); List of Published Papers from the Thesis (2 papers); and 37 tables, 3 figures, and graphs.

**Chapter 1. OVERVIEW**

**1.1. The interaction between iron and zinc and the study of the effectiveness of zinc supplementation**

When iron and zinc are used together through fortification of food with micronutrients or through supplementation, it is important to note that these two minerals have biological interactions with each other. Due to similar mechanisms of absorption and transport at the chemical level, iron and zinc are believed to compete for absorption. Cell culture studies have shown that iron inhibits the absorption of zinc in some cells when the iron:zinc ratio is very high. However, further research is needed to understand the inverse relationship between these minerals when supplemented in low iron:zinc ratios on the status of iron, zinc, other micronutrients, and disease conditions. Evaluating the effectiveness of supplementing iron or zinc separately on the status of other micronutrients (iron affecting zinc and zinc affecting iron) helps us understand more about the related adverse effects of supplement use at a 1:1 or 2:1 ratio compared to recommended intakes. Kordas and Stoltzfus proposed a hypothesis about micronutrient interactions in the gut. Both iron and zinc have important roles in body systems and have the potential to interact in organs such as the nervous system. Although separate functions of iron and zinc on the nervous system have been studied, research on the combined effects of iron and zinc is still limited. Therefore, further studies are needed to investigate the effects or impacts of iron and zinc supplementation/enhancement on growth, development, and disease risk.

Zinc can affect iron absorption, and conversely, iron can also affect zinc absorption. To minimize this effect, iron and zinc have been added to food in a 1:1 iron:zinc ratio. In the small intestine of healthy adults, when the ratio of iron sulfate to zinc sulfate is 1:1, the inhibition of zinc absorption is small, but when this ratio is 2:1 or 3:1, the inhibition of zinc absorption increases.

**1.2. The necessity of supplementing iron and zinc for children under 5 years old.**

Children under 5 years old are at high risk of iron and zinc deficiencies. Supplementary foods that do not provide enough iron for children from 6 months old can lead to iron deficiency. Low birth weight infants are at a higher risk of iron deficiency, and the rate of deficiency is faster than in children with normal weight. The diets of children under 5 years old in developing countries often contain little meat and seafood. Zinc supplementation is not yet recommended daily, but zinc has the effect of reducing the incidence of diarrhea and pneumonia. The World Health Organization has guidelines for using zinc to treat diarrhea in children under 5 years old.

**Chapter 2. OBJECTIVES AND RESEARCH METHODS**

**2.1. Subject and study location**

**2.1.1. Subject of study**

* Children aged 1-3 years old.
* Mothers (or caregivers) with children aged 1-3 years old.

**2.1.2. Location of study**

Purposeful selection was used for the study location and data collection, which were mountainous communes in Phu Tho province, a poor and mountainous area. To diversify the study population, participants were also recruited from different locations in the Northern region. Two additional provinces, Vinh Phuc and Ha Nam, were selected for this purpose.

**2.2. Research methods**

**2.2.1. Study design**

Community-based intervention with control group to compare the effectiveness of different forms of nutritional supplementation. Phase 1: Pre-intervention assessment: Evaluate the nutritional status of the selected subjects, who are children with severe acute malnutrition, through general information, anthropometric measurements, and blood tests for serum Hb, ferritin, and zinc levels. Randomly allocate the children into three study groups, ensuring equal distribution of the selected criteria on anthropometry and biochemistry among the severe acute malnourished (SAM) children in the three groups. Phase 2: Intervention activities: Implement the intervention over 6 months with three study groups. Group 1 uses a supplement containing 15mg zinc/day, group 2 uses a supplement containing 15mg iron/day + 15mg zinc/day, and group 3 is the control group using a daily supplement that does not contain iron or zinc. Post-intervention evaluation: Measure the anthropometric indices and blood levels of Hb, ferritin, and zinc to compare the effectiveness of the intervention among the study groups. Only data from children who use the supplement for more than 80% of the intervention period and use over 95% of the supplement products will be used in the analysis.

**2.2.2. Sample size**

Sample size: Applying the formula for the difference in means between two study groups at the end of the intervention

With a total sample size needed for the study of 342 malnourished children in 3 provinces, each province needs 114 malnourished children.

**2.2.3. Sampling selection**

* Province selection: Purposefully choose 3 provinces, including Phu Tho, Vinh Phuc, and Ha Nam.
* District selection: In each participating province, purposively select 1 district with a high prevalence of stunting and wasting among children.
* Commune selection: In each selected district, purposively choose 4 communes with a high prevalence of stunting and wasting among children.
* Participant selection: In the selected communes, weigh and measure children aged 1-3 years old who are on the list of children with stunting and wasting. This list is managed and updated by the commune health station according to the regulations of the program to improve the nutritional status of children under 5 years old. From this list, the research team selects an appropriate number of children based on the study requirements and the criteria of weight, height, Hb, zinc, and serum ferritin distribution among children with stunting and wasting for the 3 study groups.

**Chapter II.** **RESEARCH RESULTS**

**3.1. The results of using combined iron-zinc, zinc alone on the conditions of stunting, underweight, wasting, anemia, iron deficiency, and zinc deficiency in malnourished children aged 1-3 years after 6 months of intervention.**

**Table 3.1. The results showed changes in the height-for-age Z-scores of the study subjects after a 6-month intervention.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **HAZ** | **Control group (n=99)** | **Zn****sup. group****(n=94)** | **Zn+Fe****sup. group****(n=99)** | **p1** |
| Before | -2,66 ± 0,65 | -2,58 ± 0,49 | -2,58 ± 0,45 | 0,814 |
| After | -2,61 ± 0,63 | -2,54 ± 0,53 | -2,56 ± 0,51 | 0,476 |
| Change | 0,05 ± 0,37 | 0,04 ± 0,34 | 0,02 ± 0,32 |  |
| p2 | 0,177 | 0,255 | 0,466 |  |

*p1: Compare two intervention groups and the control group at the same time using the ANOVA Test.*

*p2: Compare the same group at two different time points before and after the intervention using paired t-Test.*

In the control group, the average height-for-age Z-score (HAZ) before the intervention was -2.66 ± 0.65, after the intervention was -2.61 ± 0.63, with a change of 0.05 ± 0.37 compared to before the intervention.

In the zinc supplementation group, the average HAZ before the intervention was -2.58 ± 0.49, after the intervention was -2.54 ± 0.53, with a change of 0.04 ± 0.34 compared to before the intervention.

In the iron-zinc supplementation group, the average HAZ before the intervention was -2.58 ± 0.45, after the intervention was -2.56 ± 0.51, with a change of 0.02 ± 0.32 compared to before the intervention.

Although there were changes in HAZ after the intervention in all groups, these changes were not statistically significant (p>0.05).

**Table 3.2. Results of changes in weight-for-age Z-scores of the study subjects after a 6-month intervention**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **WAZ** | **Control group (n=99)** | **Zn****sup. group****(n=94)** | **Zn+Fe****sup. group****(n=99)** | **p1** |
| Before | -2,13 ± 0,69 | -2,04 ± 0,62 | - 2,01± 0,58 | 0,343 |
| After | -1,81 ± 0,68 | -1,62 ± 0,67 | - 1,65 ± 0,57 | 0,103 |
| Change | 0,32 ± 0,33 | 0,42 ± 0,37 | 0,36 ± 0,30 |  |
| **p2** | **0,001** | **0,001** | **0,001** |  |

*p1: Compare two intervention groups and the control group at the same time using the ANOVA Test.*

*p2: Compare the same group at two different time points before and after the intervention using paired t-Test.*

Table 3.2 presents the average WAZ values of the study groups. In the control group, the average WAZ value before the intervention was -2.13 ± 0.69, after the intervention was -1.81 ± 0.68, and the change in WAZ after the intervention compared to before the intervention was 0.32 ± 0.33.

In the zinc supplementation group, the average WAZ value before the intervention was -2.04 ± 0.62, after the intervention was -1.62 ± 0.67, and the change in WAZ after the intervention compared to before the intervention was 0.42 ± 0.37.

In the iron-zinc supplementation group, the average WAZ value before the intervention was -2.01 ± 0.58, after the intervention was -1.65 ± 0.57, and the change in WAZ after the intervention compared to before the intervention was 0.36 ± 0.30.

There is a statistically significant difference in WAZ values before and after the intervention in all groups (p<0.05).

**Table 3.3. Results of changes in weight-for-height Z-scores of the study subjects after a 6-month intervention.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **WHZ** | **Control group (n=99)** | **Zn****sup. group****(n=94)** | **Zn+Fe****sup, group****(n=99)** | **p1** |
| Before | -0,97 ± 0,87 | -0,90 ± 0,81 | -0,85 ± 0,76 | 0,553 |
| After | -0,47 ± 0,91 | -0,29 ± 0,85 | -0,29 ± 0,74 | 0,201 |
| Change | 0,50 ± 0,55 | 0,61 ± 0,54 | 0,56 ± 0,48 |  |
| **p2** | **0,001** | **0,001** | **0,001** |  |

*p1: Compare two intervention groups and the control group at the same time using the ANOVA Test.*

*p2: Compare the same group at two different time points before and after the intervention using paired t-Test.*

Table 3.3 shows the average WHZ values in the groups before and after the intervention. The change in WHZ values compared to before the intervention in the control group is 0.50 ± 0.55; in the zinc supplementation group is 0.61 ± 0.54; and in the iron-zinc supplementation group is 0.56 ± 0.48. The change in average WHZ values before and after the intervention in all groups is statistically significant (p = 0.001).

**Table 3.4. Changes in the concentration of Hb of the study subjects after a 6-month intervention.**

| **Hb (g/L)** | **Control group (n=99)** | **Zn****sup. group****(n=94)** | **Zn+Fe****sup, group****(n=99)** | **p1** |
| --- | --- | --- | --- | --- |
| Before | 114,1 ± 10,1 | 113,8 ± 11,4 | 116,3 ± 12,1 | 0,246 |
| After | 117,3 ± 11,6 | 117,2 ± 12,6 | 118,9 ± 13,3 | 0,581 |
| Change | 3,2 ± 12,7 | 3,4 ± 13,6 | 2,6 ± 14,9 | 0,911 |
| **p2** | **0,015** | **0,019** | 0,098 |  |

*p1: Compare two intervention groups and the control group at the same time using the ANOVA Test.*

*p2: Compare the same group at two different time points before and after the intervention using paired t-Test.*

The differences in changes in Hb concentration between before and after the intervention are presented in Table 3.4. After the intervention, Hb concentration increased in all three groups: the control group increased by an average of 3.2 ± 12.7 g/L, which showed a significant difference compared to before the intervention (p = 0.015); the zinc supplementation group increased by 3.4 ± 13.6 g/L, and the iron-zinc supplementation group increased by 2.6 ± 14.9 g/L. However, there were no statistically significant differences compared to before the intervention (p = 0.098).

**3.2. Improvement in iron deficiency status after 6 months of intervention.**

**Table 3.5. Changes in serum ferritin concentration of study participants after 6 months of intervention.**

|  |  |  |
| --- | --- | --- |
| **Serum Ferritin concentration (μg/L)** | **Group** | **p1** |
| **Control (n=99)** | **Zn sup.** **(n=93)** | **Fe+Zn sup.** **(n=97)** |
| **Before** | 27.8 ± 21.6 | 30.8 ± 24.2 | 26.4 ± 16.1 | 0.767 |
| **After** | 43.8 ± 32.7 | 40.2 ± 29.0 | 50.9 ± 38.9 | **0.017** |
| **Change** | 16.1 ± 31.3 | 9.4 ± 24.6 | 24.5 ± 37.9 | **0.001** |
| **p2** | **0.001** | **0.001** | **0.001** |  |

*p1: Compare the intervention group and the control group at the same time point using ANOVA test. p2: Compare within-group changes before and after the intervention using paired t-test.*

Comparison of the difference in serum Ferritin concentration before and after intervention is presented in Table 3.5. After the intervention, serum Ferritin concentration increased in all 3 groups: the control group increased by a mean of 16.1 ± 31.3 µg/L, with a significant difference compared to before the intervention (p = 0.001); the zinc-supplemented group increased by 9.4 ± 24.6 µg/L, with a significant difference compared to before the intervention (p = 0.001); the iron-zinc-supplemented group increased by 24.5 ± 37.9 µg/L, with a significant difference compared to before the intervention (p = 0.001).

**Table 3.6 shows the changes in the proportion of iron-deficient subjects after 6 months of intervention.**

|  |  |  |
| --- | --- | --- |
| **Proportion iron-deficient (%)** | **Group** | **p1** |
| **Control (n=99)** | **Zn sup.** **(n=93)** | **Fe+Zn sup.** **(n=97)** |
| **Before** | 26.3% | 23.7% | 21.6% | 0.749 |
| **After** | 8.1% | 14.0% | 5.2% | 0.112 |
| **Change** | 16.2% | 9.7% | 16.4% | 0.253 |
| **p2** | **0.001** | 0.093 | **0.001** |  |

*p1: Compare the intervention group and control group at the same time using Chi-Square test. p2: Compare the same group at two time points before and after the intervention using McNemar test.*

Comparison of the prevalence of iron deficiency before and after intervention is presented in Table 3.6. Before the intervention, the prevalence of iron deficiency in the control group was 26.3%, in the zinc-supplemented group was 23.7%, and in the iron-zinc supplemented group was 21.6%. After 6 months of intervention, the prevalence of iron deficiency decreased in all three groups, with 8.1% in the control group, 14.0% in the zinc-supplemented group, and 5.2% in the iron-zinc supplemented group. The change in prevalence in the groups was as follows: 16.2% in the control group, 9.7% in the zinc-supplemented group, and 16.4% in the iron-zinc supplemented group. The changes in the prevalence of iron deficiency before and after intervention in the control group and iron-zinc supplemented group were statistically significant (p<0.05).

**Table 3.7. Efficacy index of intervention for iron deficiency status after intervention.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Indicator** | **Control group** | **Zn****supplementation group** | **p** |
| **Iron deficiency** | 9 | 9.1% | 14 | 14.0% | 0.29 |
| **Normal** | 90 | 90.9% | 87 | 86.0% |
| **ARR** | -4.9  |  |
| **NNT** | -20.41  |  |
| **Indicator** | **Control group** | **Fe+Zn****supplementation group** | **p** |
| **Iron deficiency** | 9 | 9.1% | 5 | 5.2% | 0.222 |
| **Normal** | 90 | 90.9% | 100 | 94.8% |
| **ARR** | 4.3  |  |
| **NNT** | 23.3  |  |

*p: Compare the intervention group and control group at the same time using Chi-Square test.*

The study results showed that after intervention, the prevalence of iron deficiency in the control group was 9.1%, 14.0% in the zinc-supplemented group, and 5.2% in the iron-zinc-supplemented group (p=0.222). The absolute risk reduction for iron deficiency between the control group and the iron-zinc-supplemented group was 6.5%. For every 23 children who used the iron-zinc-fortified biscuit, one child was not iron deficient (NNT = 23.3).

**3.3. Improvement in zinc deficiency after 6 months of intervention**

**Table 3.8. Changes in serum zinc levels of study participants.**

|  |  |  |
| --- | --- | --- |
| **Serum zinc (μmol/L)** | **Group** | **p1** |
| **Control (n=99)** | **Zn sup.** **(n=93)** | **Fe+Zn sup.** **(n=97)** |
| **Before** | 9.16 ± 1.96 | 9.16 ± 1.66 | 9.22 ± 1.75 | 0.964 |
| **After** | 9.48 ± 1.82  | 10.54 ± 2.10 | 10.54 ± 2.53 | **0.001** |
| **Change** | 0.32 ± 2.52 | 1.38 ± 2.88 | 1.31 ± 3.30 |  |
| **p2** | 0.207 | **0.001** | **0.001** |  |

*p1: Compare the intervention group and the control group at the same time point using ANOVA test. p2: Compare within-group changes before and after the intervention using paired t-test.*

Table 3.8 shows: In the control group, the serum zinc concentration before intervention was 9.16 ± 1.96 μmol/L, after intervention was 9.48 ± 1.82 μmol/L, with a change of 0.32 ± 2.52 μmol/L compared to before intervention. In the zinc-supplemented group, the serum zinc concentration before intervention was 9.16 ± 1.66 μmol/L, after intervention was 10.54 ± 2.10 μmol/L, with a change of 1.38 ± 2.88 μmol/L compared to before intervention. In the iron-zinc supplemented group, the serum zinc concentration before intervention was 9.22 ± 1.75 μmol/L, after intervention was 10.54 ± 2.53 μmol/L, with a change of 1.31 ± 3.30 μmol/L compared to before intervention. There was a significant difference in the serum zinc concentration before and after intervention in the zinc-supplemented group (p=0.001) and iron-zinc supplemented group (p=0.001).

**Table 3.9. Reduction in the prevalence of zinc deficiency among study subjects after 6 months of intervention.**

|  |  |  |
| --- | --- | --- |
| **Zinc deficiency (%)** | **Group** | **p1** |
| **Control (n=99)** | **Zn sup.** **(n=93)** | **Fe+Zn sup.** **(n=97)** |
| **Before** | 66.7 | 61.3 | 69.1 | 0.513 |
| **After** | 65.7 | 40.9 | 47.4 | **0.002** |
| **Change** | 1.0 | 20.4 | 21.7 |  |
| **p2** | 1.000 | **0.011** | **0.009** |  |

*p1: Compare the intervention group and control group at the same time using Chi-Square test. p2: Compare the same group at two time points before and after the intervention using McNemar test.*

Comparison of zinc deficiency rates before and after intervention is presented in Table 3.9. Zinc deficiency rates before intervention were as follows: control group 66.7%, zinc-supplemented group 61.3%, iron-zinc supplemented group 69.1%. After intervention, the deficiency rates were as follows: control group 65.7%, zinc-supplemented group 40.9%, iron-zinc supplemented group 47.4%.

The change in zinc deficiency rates in the control group decreased by 1.0%, in the zinc-supplemented group decreased by 20.4%, and in the iron-zinc supplemented group decreased by 21.7%. There was a statistically significant difference in the reduction of zinc deficiency rates before and after intervention in the zinc-supplemented group (p = 0.011) and iron-zinc supplemented group (p = 0.009).

**Table 3.10. Effectiveness index for zinc deficiency status after intervention.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Indicator** | **Control group** | **Zn****supplementation group** | **p** |
| **Zinc deficiency** | 65 | 65.70% | 38 | 40.90% | 0.750 |
| **Normal** | 34 | 34.30% | 55 | 59.10% |
| **ARR** | 24.8  |  |
| **NNT** | 4.03  |  |
| **Indicator** | **Control group** | **Fe+Zn****supplementation group** | **p** |
| **Zinc deficiency** | 65 | 65.70% | 46 | 47.40% | 0.010 |
| **Normal** | 34 | 34.30% | 51 | 52.60% |
| **ARR** | 18.3  |  |
| **NNT** | 5.46  |  |

*p: Compare the intervention group and control group at the same time using Chi-Square test.*

After the intervention, the prevalence of zinc deficiency in the control group was 65.70%, in the zinc-supplemented group it was 40.90%, and in the iron-zinc-supplemented group it was 47.4%. The absolute risk reduction of zinc deficiency between the control and zinc-supplemented group was 24.8%. For every four children who used zinc supplements for 6 months, one child did not have zinc deficiency (NNT = 4.03).

The absolute risk reduction of zinc deficiency between the control and iron-zinc-supplemented group was 18.3%. To prevent one child from having zinc deficiency, iron-zinc supplementation was needed for five children with zinc deficiency (NTT = 5.46), and the difference was statistically significant (p < 0.05).

**Chapter 4. DISCUSSION**

**4.1. Undernutrition, Stunting, Anemia, Iron Deficiency, and Zinc Deficiency in 1-3 Year Old Children**

**4.1.1. Nutritional status of study subjects with undernutrition and stunting**

***The status of underweight in the study subjects.***

 Examining the prevalence of underweight in the study population by gender and age showed that the highest proportion was in the 3-year-old group, while the lowest proportion was in the 2-year-old group. Regarding the prevalence of underweight by gender and age, at 1 year old, the proportion was higher in girls than boys, but at 2 and 3 years old, it was the opposite, with boys having a higher proportion than girls.

 The prevalence of underweight in the study population was much higher than that of children under 5 years old nationwide in 2020 (12.8%). Underweight is a consequence of low height-for-age and thinness. The prevalence of underweight was investigated nationwide in 2020 for children with and without stunted growth. Our study population consisted of children with both underweight and stunted growth, which explains the high prevalence of underweight in the 1-3 year old age group in the study area.

***The status of stunting in the study subjects.***

 The prevalence of stunting among the study population was 8.5%, with the highest rate in Vinh Phuc and the lowest in Phu Tho. When considering gender, the rate of stunting in boys was higher than that in girls. Similarly, when looking at age groups from 1 to 3 years old by gender, the rate of stunting in boys was higher than in girls. This rate is higher than the prevalence of stunting found in another study in Phu Tho (7.4%), as well as the national survey data (6.5%).

 The prevalence of stunting in the age groups studied in this research was 15.3% in boys aged 12-23 months, 10.2% in boys aged 36-47 months, and 10.6% in girls aged 12-23 months. These are high-risk groups for acute illnesses such as respiratory infections and diarrhea, which are contributing factors to the increased prevalence of underweight malnutrition. Repeated acute illnesses lead to poor food intake, and without timely prevention and treatment, this can lead to stunting malnutrition. If not provided with proper nutrition care during the first 2 years of life, these stunted malnourished children are at high risk of developing non-communicable chronic diseases such as diabetes, hypertension, and obesity in adulthood.

**4.1.2. The status of iron, anemia deficiency, and zinc deficiency of the study subjects.**

***The status of iron, anemia deficiency in the study subjects.***

 Consideration of the iron deficiency status of the study subjects by gender and age: In general, the prevalence of iron deficiency is higher in boys than in girls, and this prevalence decreases with age. Specifically, in the 1 and 2-year-old age groups, the prevalence of iron deficiency is higher in boys than in girls, but in the 3-year-old age group, the prevalence of iron deficiency is similar in both genders.

The prevalence of anemia in malnourished children, especially those with low weight-for-height, is usually higher than in non-malnourished children. The prevalence of anemia in studies conducted in Phu Tho and Ha Nam provinces, where the subjects are from poor areas or are malnourished children with low weight-for-height, is higher than the national average. There are various factors that contribute to anemia, and almost half of the cases of anemia in children are due to iron deficiency. To prevent anemia, it is necessary to prevent malnutrition and improve the nutritional status. Conversely, good nutritional status contributes to the prevention of anemia. Children with good nutritional status usually have better appetite, absorb nutrients better, and are less susceptible to diseases, thus reducing the risk of anemia.

***Zinc deficiency status of the study subjects.***

 The zinc deficiency rate of the study population is quite high, with about two-thirds being deficient in zinc before intervention. In the body, zinc is an important mineral that plays a role in cell growth and differentiation, protein and lipid metabolism, and immune function. Zinc is necessary for metabolic activities including digestion and synthesis, breakdown of nutrients, and regulatory functions. Zinc deficiency in children can cause slow growth and poor appetite. It has been found that in children aged 3-5 years, the zinc intake is only 75.7% of the recommended dietary allowance and serum zinc levels are positively correlated with weight and height. Our study population consists of children with low weight-for-height due to malnutrition, which explains the high rate of zinc deficiency in these children.

**4.2.** **The results of using combined iron-zinc supplementation with separate zinc supplementation on the conditions of stunting, underweight, wasting, anemia, iron deficiency, and zinc deficiency in 1-3 year old children with stunted growth after 6 months of intervention.**

**4.2.1. Characteristics of study subjects.**

***Biometric characteristics of study subjects in the research groups:***

 The biometric characteristics of the study subjects at baseline were divided into 3 equally sized groups: with mean age ranging from 29.22 ± 10.04 to 30.01 ± 10.40 years; mean weight ranging from 10.05 ± 1.46 kg to 10.11 ± 1.54 kg; mean height ranging from 81.46 ± 6.17 cm to 81.77 ± 6.22 cm; the mean height-for-age Z-score of the study subjects was -2.57 ± 0.44 to -2.64 ± 0.62; the mean weight-for-age Z-score of the study subjects was -1.97 ± 0.59 to -2.11 ± 0.69, and the mean weight-for-height Z-score of the study subjects was -0.79 ± 0.77 to -0.95 ± 0.87. These characteristics indicate that all three groups had a mean height-for-age Z-score of less than -2SD, corresponding to the weight-for-age Z-score of two groups below -2SD and one group close to -2SD. Being underweight is a consequence of both stunting and wasting. The study subjects were undernourished stunted children, which explains the high prevalence of underweight children aged 1-3 years in the study area.

**4.2.2. Intervention results for stunting malnutrition.**

 When considering the intervention results of the change in Z-score height-for-age of the study subjects after 6 months of intervention, all three groups showed changes. In the control group, the mean change in HAZ score decreased to -0.05 ± 0.37, while in the zinc-supplemented group, the mean change in HAZ score decreased to -0.04 ± 0.34, and in the iron-zinc supplemented group, the mean change in HAZ score decreased to -0.02 ± 0.32. The change in HAZ score after intervention decreased compared to before intervention in all three groups, but it was not statistically significant (p>0.05). Although there were changes, compared to the control group, the intervention group had lower changes. The changes in this study were lower than those in Nguyen Anh Vu's study on stunted children aged 12 to 23 months. The average increase in HAZ score in the intervention group was 0.50 ± 0.96, much higher than that of the control group, which was 0.05 ± 1.17, and the difference was statistically significant with p < 0.05. Our HAZ score increase was slightly lower than that in Bui Dai Thu's study on nutritional supplementation intervention (0.48) and slightly lower than that in the 6-month intervention study on multiple nutrient supplementation combined with deworming in children under 24 months in Quang Tri (HAZ increased by 0.43 ± 0.29).

 The results of the intervention showed a change in the proportion of low weight-for-height malnutrition in all three groups, with changes in the proportion of low weight-for-height malnutrition before and after the intervention: in the control group, 8 out of 99 children had a proportion of 8.1% after 6 months of intervention; in the Zn-supplemented group, 15 out of 83 children recovered from low weight-for-height malnutrition, accounting for 18%; and in the Fe-Zn-supplemented group, 10 out of 90 children recovered from low weight-for-height malnutrition, accounting for 11.1%. The changes in the proportion of low weight-for-height malnutrition before and after the intervention in all three groups were statistically significant (p<0.05). Compared to the study by Nguyen Anh Vu, the proportion of low weight-for-height malnutrition in the control group decreased from 100% to 63.1% after the intervention, while the intervention group decreased to 44.6%. The effectiveness index of the control and intervention groups was 36.9% and 55.4%, respectively. In our study, the results of the intervention in reducing the proportion of low weight-for-height malnutrition were lower than those of Nguyen Thanh Ha's study in 2011, where the proportion of low weight-for-height malnutrition decreased by 40.7% in children aged 6-36 months over 6 months.

 In terms of effectiveness indicators for the low weight-for-height malnutrition status after intervention, the results also show that children who were supplemented with zinc and the iron-zinc group after 6 months had a significant reduction in the absolute risk of low weight-for-height malnutrition, with a reduction rate of 7.9% (ARR= 7.9) for the zinc group, which was higher than the group of children who were supplemented with iron alone. When children were given the iron-zinc supplement for 6 months, 13 children who ate the zinc supplement cake escaped from low weight-for-height malnutrition (NNT= 12.66), which was higher than the result for children who were given the Fe+Zn supplement and had one child escape from low weight-for-height malnutrition (NNT= 50).

**4.2.3. Intervention results for underweight malnutrition.**

 The results of the change in Z-score weight/age of the study subjects after 6 months of intervention showed that the average WAZ score in the intervention group decreased compared to the pre-intervention score, with a decrease of -0.32±0.33 in the control group, -0.42±0.37 in the zinc-supplemented group, and -0.36±0.30 in the iron-zinc supplemented group. The changes before and after the intervention of all groups were statistically significant (p<0.05). Similarly, a study on undernourished children aged 12-23 months in Tien Lu district, Hung Yen province in 2017 showed that the WAZ score for weight by age of both the control and intervention groups improved significantly. The average increase in WAZ score of the intervention group was 0.41±1.11, which was statistically significant compared to the control group with an increase of 0.07±1.15 (p<0.05), and similar to the results of Tran Thi Lan's study on a 6-month intervention combining multiple micronutrient supplements with deworming for children under 24 months in Quang Tri, where the WAZ increase was 0.40±0.29.

 Regarding the change in the rate of mild malnutrition after 6 months of intervention, there was a statistically significant change in the rate of mild malnutrition before and after the intervention in all three groups (p<0.05). The rate of mild malnutrition in the control group decreased by 18%, while the zinc-supplemented group decreased by 22.8% and the iron-zinc supplemented group decreased by 14.3%. Compared to the study of supplemented existing products in Hung Yen in 2017, our study showed a lower decrease in the rate of mild malnutrition in the intervention group than the study on improving the rate of mild malnutrition after 12 months for both groups in Hung Yen (the control group decreased from 18.5% to 10.8%, and the intervention group decreased from 26.1% to 6.1%).

 Regarding the effectiveness index, the results showed that after the intervention, the zinc-supplemented group had a higher percentage of non-mild malnourished subjects (70.2%) than the control group (63.6%). The effectiveness index showed a relative risk reduction for stunting of 6.6%. The results also showed that for every 15 children who used zinc-enriched biscuits for 6 months, one child did not have mild malnutrition (NTT= 15.15). At the time of the iron-zinc supplementation intervention, 69.7% of the subjects in the intervention group were not mildly malnourished, which was higher than the control group (63.6%). The effectiveness index of the intervention in reducing the risk of mild malnutrition was 6.1%, and for every 16 children receiving iron-zinc supplementation, one child did not have mild malnutrition. (NNT=16,39).

 The results of intervention for mild malnutrition with zinc supplementation and iron-zinc supplementation showed changes in Z-score weight-for-age index that were relatively equivalent to the control group (in the zinc supplementation group, WAZ score increased by 0.1, and in the iron-zinc supplementation group, WAZ score increased by 0.06) and were statistically significant (p<0.05).

**4.2.4. The results of changes in the underweight malnutrition status after 6 months of intervention.**

 The results of the intervention for mild malnutrition with zinc supplementation and iron-zinc supplementation compared to the control group showed changes in the Z-score weight/age index that were nearly equivalent to each other (in the zinc supplementation group, the WAZ index increased by 0.1 and in the iron-zinc supplementation group, the WAZ index increased by 0.06), and had statistical significance (p<0.05).

 The results of changes in the status of underweight malnutrition after 6 months of intervention showed the average WHZ score in the groups before intervention, after intervention, and changes compared to before intervention decreased as follows: control group -0.97 ± 0.87, -0.47 ± 0.91, -0.50 ± 0.55; Zinc supplementation group -0.90 ± 0.81, -0.29 ± 0.85, -0.61 ± 0.54; Iron-zinc supplementation group -0.85 ± 0.76, -0.29 ± 0.74, -0.56 ± 0.48. The changes before and after intervention in all groups were statistically significant (p<0.05), and the average WHZ score in all groups increased. In the zinc supplementation group, the average WHZ score increased by 0.11 compared to the control group, and in the iron-zinc supplementation group, the average WHZ score increased by 0.06 compared to the control group.

 Regarding the results of changes in the proportion of underweight malnutrition after intervention in all three groups, there were changes in the proportion of underweight malnutrition after intervention. In the zinc supplementation group, there were 10 subjects with underweight malnutrition before intervention, accounting for 8.8% of the group, and after intervention, there was only 1 subject, accounting for a change of 7.7%, which was higher than the control group's change of 5.4%. As for the iron-zinc supplementation group, the change in the proportion of underweight malnutrition was low (4.2%), and this change was not statistically significant (p<0.05).

**4.2.5.****Results of using combined iron-zinc supplementation compared to zinc supplementation alone on anemia status.**

 Change in Hb concentration of the study subjects after 6 months of intervention showed a difference between pre- and post-intervention. After intervention, Hb concentration increased in all three groups. In the control group, the mean increase in Hb concentration was 3.2 ± 12.7 g/L, in the zinc-supplemented group, it was 3.4 ± 13.6 g/L. In the iron-zinc supplemented group, the mean increase in Hb concentration was 2.5 ± 14.9 g/L (p = 0.098). Both control and zinc-supplemented groups showed a statistically significant increase in Hb concentration before and after the intervention (p<0.05). Although the Hb concentration increased in both intervention groups, the difference in the increase compared to the control and zinc-supplemented groups was not significant (an increase of only 0.02 g/L) and the iron-zinc supplemented group did not show an increase in Hb concentration compared to the control group. The comparison of the proportion of anemia before and after 6 months of intervention, to evaluate the effectiveness of reducing anemia after intervention, showed that the proportion of anemia in the control group not only did not decrease but increased from 30.3% to 33.3%, while the proportion of anemia in the zinc-supplemented group decreased by 5.4% and in the iron-zinc supplemented group decreased by 6.2%. The comparison between the two intervention groups showed that iron-zinc supplementation reduced the proportion of anemia more than zinc supplementation by 1.8%. However, the level of change in the proportion of anemia before and after intervention in all three groups was not statistically significant (p>0.05).

 The efficacy index of intervention on anemia after intervention. The efficacy of the intervention reduced the absolute risk of anemia by 2.1%, and in the zinc-supplemented group, for 48 anemic children, one child was not anemic (NNT=47.62); in the control group and iron-zinc supplemented group after intervention, the proportion of non-anemic children was 66.70% and 76.30%, respectively. The efficacy of intervention reduced the absolute risk of anemia by 9.6%, and in the iron-zinc supplemented group, for 10 anemic children, one child was not anemic (NNT=10.42). The difference was not statistically significant (p>0.05).

 The proportion of anemia in the zinc-supplemented group decreased by 5.4% (from 36.6% to 31.2%), and in the iron-zinc supplemented group, it decreased by 6.2% (from 29.9% to 23.7%). The results showed that the difference in the proportion of anemia before and after intervention was not statistically significant. However, the trend of decreased anemia proportion in the zinc and iron-zinc supplemented groups suggested that using food supplements of 15 mg of zinc alone or combined with 15 mg of iron may be effective in reducing anemia.

The reduction in the anemia rate from our study is equivalent to the results of a randomized controlled trial in the Philippines, where the Hb concentration of children using iron-fortified rice increased and the anemia rate decreased by 4.7% between two time points before and after the intervention.

 The results of using combined iron-zinc supplementation compared to zinc supplementation alone on the anemia status, the anemia rate after 6 months of intervention compared to before intervention in stunted children aged 1-3 years showed an increase in the anemia rate in the control group. Comparing the effectiveness of zinc supplementation alone, which decreased the anemia rate by 5.4%, and combined iron-zinc supplementation, which decreased the anemia rate by 6.2%, shows that adding iron-zinc reduces the anemia rate more than just adding zinc. The intervention efficacy index comparing combined iron-zinc supplementation and zinc supplementation alone did not show statistical significance (p>0.05).

**4.2.6. Improved iron deficiency status after 6 months of intervention**

 Change in serum Ferritin levels of the study subjects after 6 months of intervention showed that the mean Ferritin levels in the pre-intervention, post-intervention, and change from pre-intervention were reduced as follows: control group 27.8 ± 21.6, 43.9 ± 32.7, 16.1 ± 31.3; zinc-supplemented group 30.8 ± 24.2, 40.2 ± 29.0, 9.4 ± 24.6; iron-zinc-supplemented group 26.4 ± 16.1, 50.9 ± 38.9, 24.5 ± 37.9. The changes before and after the 6-month intervention in all groups were statistically significant (p<0.05).

 The study results showed an improvement in serum Ferritin levels in all three groups, with the iron-zinc-supplemented group having the highest improvement of 24.5 μg/L, which was higher than the zinc-supplemented group at 9.4 μg/L. Meanwhile, the control group also showed an improvement in serum Ferritin levels, higher than the zinc-supplemented group. This suggests that, over time, along with the energy supply from the supplementary snack of 56.25 kcal/day, Ferritin improved. Due to the interaction with zinc, the ability to absorb iron was affected, and the level of Ferritin improvement in the zinc-supplemented group was lower than that in the control group. On the other hand, due to the combined iron and zinc supplementation in the iron-zinc-supplemented group, the iron absorption and storage ability were better than those in the zinc-supplemented group.

 The results of improving iron deficiency after a 6-month intervention in stunted children aged 1-3 years showed that the mean Ferritin levels in all post-intervention groups changed compared to pre-intervention, and decreased compared to the control group, as follows: the zinc-supplemented group did not increase compared to the control group, while the iron-zinc-supplemented group increased higher than the control group. The changes before and after the 6-month intervention in all groups were statistically significant (p<0.05). On the other hand, the changes in the prevalence of iron deficiency after intervention were observed in all three groups, but the decrease in iron deficiency prevalence was lower in the zinc-supplemented group than in both the control and iron-zinc supplemented groups. Comparing the changes in iron deficiency prevalence after intervention, the iron-zinc supplemented group had a greater decrease in iron deficiency prevalence than the zinc-supplemented group. The changes in iron deficiency prevalence before and after intervention in all three groups were statistically significant (p<0.05). The combined iron-zinc supplementation resulted in a better outcome compared to zinc supplementation alone in reducing iron deficiency prevalence after 6 months of intervention in stunted and underweight children aged 1-3 years with malnutrition.

**4.2.7.** **Improved zinc deficiency status after intervention**

Changes in serum zinc levels of the study participants after 6 months of intervention were examined. Analysis of the average change in serum zinc levels showed that all 3 groups had an increase in serum zinc levels after 6 months of intervention: in the control group, the change compared to before the intervention increased by 0.32 ± 2.52; in the zinc-supplemented group, the change compared to before the intervention increased by 1.38 ± 2.88; in the iron-zinc-supplemented group, the change compared to before the intervention increased by 1.31 ± 3.30. Comparison between the zinc-supplemented group and the control group showed that the zinc-supplemented group had a higher increase in serum zinc levels by 1.08 μmol/L, while comparison between the iron-zinc-supplemented group and the control group showed that the iron-zinc-supplemented group had a higher increase in serum zinc levels by 0.99 μmol/L. The results showed that the increase in serum zinc levels in both the iron-zinc-supplemented group and the zinc-supplemented group was equivalent. The changes before and after intervention in both zinc-supplemented and iron-zinc-supplemented groups were statistically significant (p<0.05).

Comparison of the zinc deficiency rate of the study participants after 6 months of intervention showed that after intervention, the change in the zinc deficiency rate in the control group decreased by 1.0%, the zinc-supplemented group decreased by 20.4%, and the iron-zinc-supplemented group decreased by 21.7%. Comparison of the decrease in zinc deficiency rate between the zinc-supplemented and control groups showed that the zinc-supplemented group had a greater decrease in zinc deficiency rate than the control group by 19.4%, while comparison of the iron-zinc-supplemented group and the control group showed that the iron-zinc-supplemented group had a greater decrease in zinc deficiency rate than the control group by 20.7%. Comparison of the effectiveness of reducing the zinc deficiency rate showed that the iron-zinc-supplemented group had a higher zinc deficiency rate than the zinc-supplemented group. The changes in the zinc deficiency rate before and after intervention in both intervention were statistically significant (p<0.05).

**CONCLUSION**

**1. Malnutrition in the form of underweight, wasting, anemia, iron deficiency, and zinc deficiency was observed in stunted children aged 1-3 years.**

* The prevalence of UNDERWEIGHT malnutrition in the study population is 50.6%, with 6.8% being severely underweight and 43.8% being moderately underweight.
* The prevalence of WASTING malnutrition in the study population is 8.5%, with 8.5% being moderately wasted.
* The prevalence of ANEMIA in the study population is 31.8%.
* The prevalence of IRON DEFICIENCY in the study population is 24.4%.
* The prevalence of ZINC DEFICIENCY in the study population is 65.3%.

**2. Results of using combined iron-zinc supplementation with zinc alone in stunted underweight 1-3 year old children after 6 months of intervention.**

***To improve the condition of stunted:***

After 6 months of intervention, the HAZ index decreased in all 3 groups compared to before the intervention, but there was no statistically significant difference (p > 0.05).

There was a significant difference in the prevalence of stunting between before and after the intervention (p < 0.01). At the end of the intervention, the prevalence of stunting in the control group decreased by 91.9%; in the group supplemented with zinc alone, it decreased by 84%, and in the group supplemented with iron-zinc, it decreased by 89.9%.

***To improve the condition of underweighted:***

The intervention results showed a change in the WAZ score, with a decrease of -0.42 ± 0.37 in the zinc-supplemented group and a decrease of -0.36 ± 0.30 in the iron-zinc supplemented group, which was higher than the control group (decrease of -0.32 ± 0.33). The change was statistically significant (p < 0.05). The proportion of underweight children decreased by 21.3% in the zinc-supplemented group, which was higher than the decrease of 19.2% in the control group (p < 0.05).

***To improve the condition of wasted:***

After 6 months of intervention, the mean WHZ score in all 3 groups decreased compared to before the intervention (p<0.05). There was a change in the proportion of underweight children in all 3 groups after 6 months of intervention. The group supplemented with zinc had a greater reduction in the proportion of underweight children compared to the control group (corresponding to 7.4% vs. 5%), and the change was statistically significant (p<0.05).

***To improve the condition of anemia deficiency:***

After the intervention, Hb concentration increased in all 3 groups. Hb concentration in the zinc-supplemented group increased by an average of 3.4 ± 13.6 g/L, which was higher than the control group: 3.2 ± 12.7 g/L (p<0.05). The Hb concentration in the iron-zinc supplemented group increased by an average of 2.6 ± 14.9 g/L (p=0.098). After the intervention, the prevalence of anemia decreased by 5.4% in the zinc-supplemented group and 6.2% in the iron-zinc supplemented group. The prevalence of anemia in the control group increased by 3%. However, the level of change in the prevalence of anemia did not reach statistical significance (p > 0.05).

***To improve the condition of ion deficiency:***

The results of the study showed changes in the average serum Ferritin concentration of the study subjects as follows: the iron-zinc supplemented group increased by 24.5 ± 37.9 μg/L, which was higher than the control group with an increase of 16.1 ± 31.3 μg/L; the zinc supplemented group increased by 9.4 ± 24.6 μg/L. The difference was statistically significant (p<0.05).

The results also showed changes in the proportion of iron deficiency as follows: the control group decreased by 16.2%, while the zinc supplemented group decreased by 9.7%, and the iron-zinc supplemented group decreased by 16.4%. The changes in the proportion of iron deficiency before and after intervention in the control group and the iron-zinc supplemented group were statistically significant (p<0.05).

***To improve the condition of zinc deficiency:***

The results of the study showed changes in the serum zinc concentration of the study subjects as follows: the zinc supplemented group increased by 1.38 ± 2.88; the iron-zinc supplemented group increased by 1.31 ± 3.30; the control group increased by 0.32 ± 2.52. The difference was statistically significant (p<0.05).

The results also showed changes in the proportion of zinc deficiency as follows: the control group decreased by 1.0%, the zinc supplemented group decreased by 20.4%, and the iron-zinc supplemented group decreased by 21.7%. The difference in the proportion of zinc deficiency before and after intervention was statistically significant in the zinc supplemented group and the iron-zinc supplemented group (p<0.05).

The efficacy index showed that the combined iron + zinc supplementation intervention reduced the absolute risk of zinc deficiency by 18.3%, and the number needed to treat (NNT) for 5 zinc-deficient children to have one less child with zinc deficiency was 5.46.

**RECOMMENDATIONS**

* Iron-zinc supplementation should be provided to undernourished stunted children aged 1-3 years in difficult areas with a high prevalence of stunting in Ha Nam, Phu Tho, and Vinh Phuc provinces with the goal of improving malnutrition, anemia, iron deficiency, and zinc deficiency.
* Further studies on a wider population of undernourished stunted children at an older age group are needed to evaluate the results of combined iron-zinc supplementation or individual zinc supplementation to provide scientific evidence and contribute to appropriate intervention solutions.
* Long-term monitoring and evaluation studies over 6, 12, and 24 months of intervention are needed to fully assess the impact of iron-zinc and zinc supplementation after intervention for undernourished stunted children aged 1-3 years.