Progress in Nutrition 2025; Vol. 27, N. 2: 16962 DOI: 10.23751/pn.v27i2.16962

Original article

Association of short chain fatty acid profile and nutritional intake of malnourished children in Indonesia

Rina Pratiwi, Farid Agung Rahmadi, Moh. Syarofil Anam, Juwita Pratiwi, Maria Mexitalia

Department of Child Health, Faculty of Medicine Universitas Diponegoro, Kariadi General Hospital

Abstract. *Background and aim:* Stunting and wasting prevalence in Indonesia are considered really high (31% and 10.2% respectively), which have been major global issue. On the gastrointestinal system of malnourished children, there are gut microbiota alterations. Dysbiosis and functional capacity change affects short-chain fatty acid (SCFA) production, causing inefficient nutrition uptake. This study aimed to analyze the correlation of SCFA profile and nutritional intake of malnourished children, including the association of risk factors in malnourished children. *Methods:* Fourty children (25 males, 15 females) with stunted and/or wasted according to World Health Organization (WHO) growth chart were included in this study. Anthropometric measurements and physical examination were done by pediatrician. Questionnare about child's gestational age, exclusive breastfeeding status, congenital disease, antibiotic consumption, and dietary intake using 3-days food recall were filled by parents/caregivers. Fecal and SCFA analysis was done by GC-MS at laboratory in Semarang, Indonesia. Intergroup differences and association were compared using Spearman and Mann-Whitney test. *Results:* Children with double malnutrition have different SCFA profile than children with single malnutrition, especially in acetic and propionic acid. There is a correlation between fibre intake and propionic acid in malnourished children (p=0.037). Antibiotic usage and malabsorption contribute significantly in SCFA profile (p=0.033, 0.016, 0.042). Fibre and leukocytes count in feces are correlated with SCFA profile (p=0.013, 0.024). *Conclusions*: There is correlation between fibre intake and propionic acid levels in malnourished children. Antibiotic usage is associated with propionic and valeric acid levels, while malabsorption is associated with butyric acid levels.

Key words: short chain fatty acid, nutritional intake, malnourished children, indonesia, stunting, wasting

Introduction

Pediatric malnutrition has been a major global issue, associated with higher morbidity and mortality. According to American Society for Parenteral and Enteral Nutrition, pediatric malnutrition is defined as an imbalance in the intake and requirements of nutrients that leads to cumulative shortfalls of energy, protein, or micronutrients that may impact negatively on growth, development, and other relevant outcomes. The term malnutrition encompasses three terminologies: undernutrition, micronutrient, and overnutrition. Based on World Health Organization (WHO) classification of nutritional status of infants and children, undernutrition was divided into moderately stunted (moderate chronic malnutrition), severely stunted (severe chronic malnutrition), moderately wasted, and severely wasted with weight-for-length/height score median below –3 SD. Pediatric malnutrition results from combination of several factors, namely availability of food resources, cultural food practice, social-economic status, healthcare facility for maternal and child care, along with government policies. United Nations Children's Fund (UNICEF) levels and trends in child malnutrition

2023 edition showed that 148 million children under the age of 5 years were stunted, 45 million wasted, and 37 million were overweight. Stunting and wasting prevalence in Indonesia are considered really high. On the report of Indonesian Health Survey in 2023, it was found that one in five toddlers in Indonesia (21.5%) experienced stunting, with the most cases from the 2-3 years age group. According to 2023 Joint Child Malnutrition Estimates data by UNICEF, World Health Organization (WHO), and World Bank Group, it is estimated that 31% child population were stunted and 10,2% child population were wasted in Indonesia (1,2). Malnutrition brings long term impacts on child's overall health status, physical growth, and cognitive development. On the gastrointestinal system of malnourished children, some alterations have been known such as intestinal permeabilty, malabsorption, and gut microbiota changes. Gut microbiota is a collection of microorganisms, composed mainly of bacteria, that plays role in producing metabolites for nutrient metabolism. One of metabolites produced is short-chain fatty acids (SCFA), resulted from fibre fermentation in colon. Major SCFAs produced in gut are acetate, propionate, and butyrate. SCFA could help regulate immune system, therefore strengthening intestinal barriers. However, there was a dysbiosis and change of functional capacity from gut microbiota in children with malnutrition. Dysbiosis is found to be associated with gut microbiota immaturity, changes of microbes' variation, and increase of pathogenic and inflammatogenic species. Moreover, gut microbiota dysbiosis affects SCFA production which will cause inefficient nutrition uptake (3–6). The aim of this study was to analyze the association of SCFA profile and nutritional intake of malnourished children, including the association of risk factors in malnourished children.

Methods

Study design

This study was an observational analytic study with cross-sectional design. It was conducted involving children with malnutrition who visited the Nutritional and Metabolic Disease clinic of tertiary hospital and outpatient therapeutic centre for malnutrition in Semarang (Indonesia) from April until August 2021.

Study population

A total of 40 children (25 boys and 15 girls) within the age of 6 months to 5 years old, with stunted and/or wasted status according to WHO growth chart were included in this study. The WHO classification of nutritional status of infants and children defined stunted and wasted as moderately stunted (moderate chronic malnutrition) with length/ height-for-age score median between ≤–2 SD and ≥–3 SD; severely stunted (severe chronic malnutrition) with length/ height-for-age score median below –3 SD of the median; moderately wasted with weight-for-length/height score median between ≤–2 SD and ≥–3 SD; severely wasted with weight-for-length/height score median below –3 SD. Sample was chosen using consecutive sampling, where each subject who met the inclusion criteria was selected until the required sample size was reached (7).

Anthropometric & dietary intake measurements

All subjects underwent full anthopometric evaluation, including weight, length/ height, upper arm circumference, head circumference, nutritional status according WHO classification; Physical examination to determine whether subjects are sick on admission; and subjects' parents/ caregivers have to filled in questionare.

- Weight and height were measured by mechanical scale (SECA, Hamburg, Germany) with light clothing and no shoes, ankles together, relaxed shoulders, and both arms at the sides of the bodies. Length were measured by mechanical scale (SECA, Hamburg, Germany) with light clothing and no shoes, lying down, both legs fully extended, from the top of head to bottom of one heels (8).
- Upper arm circumference was measured by nonstretchable tape measure (SECA, Hamburg, Germany) at the midpoint between the acromion and olecranon processes, arm flexed at 90° (8).
- Head circumference was measured by nonstretchable tape measure (SECA, Hamburg,

Germany) from the occiput to supraorbital ridge (8).
- Nutritional status was measured according WHO classification of nutritional status of infants and children, using Height-for-Age z score (HAZ) chart, Weight-for-Age z score (WAZ) chart, Weight-for-Length z score (WHZ) chart (7).
- Physical examination was done thoroughly by head-to-toe examination, carried out by a pediatrician
- Data taken from questionnaire filled in by parents/ caregivers, such as child's gestational age, whether the child received exclusive breastfeeding, had congenital disease, had antibiotic consumption in the past month, and child's dietary intake using 3-days food recall

Fecal and SCFA analysis

The children and their parents/ caregivers had consented to give the stool collection containers and taught the collection procedure. Fecal samples were collected from children at their home in the morning, collected in a clean container, and sent to the laboratory. Macroscopic fecal analysis was carried out to determine if there was any mucus or blood in the feces, while microscopic fecal analysis was carried out to determine if there was any fat, carbohydrate, fibre, erythrocytes, leukocytes, occult blood, fungus, or malabsorption. For SCFA examination, parent needed to obtain 2-5 grams fresh fecal samples and sent directly to laboratory and stored under stable condition at 4-8°C temperature. SCFA quantification was done using Gas Chromatography-Mass Spectrometry (GC-MS) method to determine total SCFA, acetic acid, propionic acid, valeric acid, and butyric acid levels. Each SCFAs were measured as percentage and total SCFA was measured as mg/dL.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics ver. 25.0 for Windows Software (IBM Co., Armonk, NY, USA). Categorical data were expressed as frequency and percentage, while numerical data was expressed as mean ± standard deviation with median, minimum and maximum data included. Shapiro-Wilk test was used for normality test, then numerical groups' data were compared using Spearman test. Mann-Whitney test was used to determined correlation between categorical and numerical groups. P value of <0.05 was considered statistically significant.

Ethical statement

All parents or caregivers agreed to participated in this study and signed the informed consent for their children. The study was approved by the Ethical Committee of Dr. Kariadi Hospital Semarang, Indonesia (No.806/EC/KEPK-RSDK/2021) and was conducted in accordance with the declaration of Helsinki with good clinical practice as defined by the International Conference on Harmonization.

Results

Subject clinical and biochemical characteristics

Patients included in this study were patients with stunted and/or wasted status according to the WHO growth chart with 37.5% patients were females and 62.5% patients were males. Average age was 19.4+12.23 months, mother's age was 30.8+6.61 years, and father's age was 34.2+6.84 years. The mean of anthropometric measurements was as follows: upper arm circumference was 121.35 + 11.35cm, head circumference was 43.5 + 3.3cm, HAZ score was -2.9 + 1.64 with minimum score -7.50, WAZ score was -3.8 + 1.01 with minimum score -6.35, WHZ score was -3.4 + 0.79 with minimum score -6. As many as 27.5% of patients were born prematurely, with 22.5% of patients had congenital disease and only 67.5% of patients were given exclusive breastfeeding. On admission, 50% of patients were sick, where 42.5% of patients were currently using antibiotic. Of all patients, 62.5% patients had double malnutrition status, while 37.5% of them had single malnutrition status. From patient's dietary recall in three days, the mean of dietary intake for energy was 1086.39 ± 182.5kcal/day, carbohydrate was

156.79 ± 29.5gr, protein was 25.63 ± 7.8gr, fat was 41.97 ± 7.63gr, fibre was 386.59 ± 1152.67 gr, PUFA was 2.53 ± 2.20gr, cholesterol 151.48 ± 175.28mg, and iron 5.81 ± 5.39mg. Patient's macroscopic fecal analysis showed that 85% of patients had mucus and none of the patients had blood. While patient's microscopic fecal analysis showed that 25% of patients had fat, 10% of patients had carbohydrate, 45% of patients had fibre, 20% of patients had erythrocytes and leukocytes, 25% of patients had occult blood, 35% of patients had fungus in their feces. 40% of patients experienced malabsorption. SCFA analysis showed the mean + standard deviation of acetic acid 66.7 ± 9.71%, propionic acid 20.17 ± 9.44%, valeric acid 1.56 ± 1.47%, butyric acid 7.92 ± 5.88%, and total SCFA 14.25 ± 6.21ng/ml as seen in Table 1.

Correlation of SCFA and nutritional intake

When SCFA was examined with nutritional intake (Table 2), it was shown that fibre intake and propionic acid levels had significant correlation with p value of 0.037 ($p<0.05$). Correlation coefficient was positive ($r=0.330$), showing moderate correlation. This implies that increasing fibre consumption will likewise raise levels of propionic acid.

Association of SCFA, Dietary Intake, and Malnutrition

Regarding of malnutrion, it has been shown that there was significant difference in acetic acid ($p=0.00$) and propionic acid ($p=0.046$) between children with single and double malnutrition. On the other hand, dietary intake had no significant difference with malnutrition (Table 3).

Association of risk factor and SCFA levels in malnourished children

Antibiotic usage had significant difference with propionic acid ($p=0.033$) and valeric acid ($p=0.016$). While malabsorption showed significant difference with butyric acid ($p=0.042$). Other risk factors related to SCFA in malnourished children such as exclusive breastfeeding, sick on admission, and congenital disease showed no significant difference with SCFA (Table 4).

Association of SCFA and fecal analysis

In relation to fecal analysis, it has been shown that there was significant difference between fibre count in feces and acetic acid ($p=0.013$). Leukocytes count in feces also had significant difference with valeric acid ($p=0.024$) as seen in Table 5.

Discussion

This study showed that children with double malnutrition (both stunted and wasted) have different SCFA profiles compared to children with single malnutrition (either stunted or wasted). SCFA production is a biochemical process carried out by human gut bacteria through fermentation. SCFA are known to have roles in helping the absorption of various nutrients, act as an immune barrier that pathogenic bacteria growth, and have antiinflammatory effects. Recent metagenomic analysis suggested that gut microbiota and SCFA products could determine children's nutritional status. In normal physiologic conditions, SCFA production is influenced by the diversity and number of microorganisms, consumption of carbohydrates, and low pH in the colon. The number of microorganisms in the normal human digestive tract is estimated to be ranging from 10^1-10^7 CFU/ml with 300-1000 different species. While recent research on malnourised children in Indonesia showed significant difference in the composition of gut microbiota between normal and malnourised children, known as dysbiosis. Stunted children also have notable gut microbiome differences, where Malnutrition and Enteric Disease cohort study showed a correlation between microbiome composition diversity and children's linear growth, although it varies geographically. On the other hand, wasted children are known to have low diversity and immature microbiota as measured by the microbiota-for-age Z-score. The shift on microbiota diversity and maturity disrupts intestinal function, delaying child's metabolism and nutrient absorption, most importantly alters production of SCFA which contributed to daily energy expenditure. Consequently, studies have supported the finding of this study where children with double malnutrition have different SCFA profiles

Table 1. Patients' clinical and biochemical characteristics

Variables		**Frequency (%)**	**Mean + SD**
Gender	Female	15 (37.5%)	
	Male	25 (62.5%)	
Gestational age	Aterm	29 (72.5%)	
	Preterm	11 (27.5%)	
Exclusive	No	13 (32.5%)	
breastfeeding	Yes	27 (67.5%)	
Antibiotic usage	Yes	17 (42.5%)	
	No	23 (57.5%)	
Sick on admission	Yes	20 (50%)	
	No	20 (50%)	
Congenital	Yes	9 (22.5%)	
disease	No	31 (77.5%)	
Malnutrition	Double	25 (62.5%)	
status	Single	15 (37.5%)	
Age (months)			19.4 + 12.23
MUAC (cm)			121.35 + 11.35
HC (cm)			43.5 + 3.3
Mother's age (years)			30.8 + 6.61
Father's age (years)			34.2 + 6.84
HAZ score			-2.9 + 1.64
WAZ score			-3.8 + 1.01
WHZ score			-3.4 + 0.79
Mucus	Yes	6 (15%)	
	No	34 (85%)	
Blood	Yes	0 (0%)	
	No	40 (100%)	
Fat	Yes	10 (25%)	
	No	30 (75%)	
Carbohydrate	Yes	4 (10%)	
	No	36 (90%)	
Fibre	Yes	18 (45%)	
	No	22 (55%)	
Erythrocytes	Yes	8 (20%)	
	No	32 (80%)	
Leukocytes	Yes	8 (20%)	
	No	32 (80%)	
Occult Blood	Yes	10 (25%)	
	No	30 (75%)	

Table 1 (*Continued*)

Variables		Frequency (%)	Mean + SD
Fungus	Yes	14 (35%)	
	No	26 (65%)	
Malabsorption	Yes	16 (40%)	
	No	24 (60%)	
Acetic acid (%)			66.7 + 9.71
Propionic acid (%)			20.17 + 9.44
Valeric acid (%)			1.56 + 1.47
Butyric acid (%)			7.92 + 5.88
Total SCFA (ng/ml)			14.25 + 6.21
Energy (kcal/day)			1086.39 ± 182.5
Carbohydrate (gr)			156.79 ± 29.5
Protein (gr)			25.63 ± 7.8
Fat (gr)			41.97 ± 7.63
Fibre (gr)			386.59 ± 1152.67
PUFA (gr)			2.53 ± 2.20
Cholestrol (mg)			151.48 ± 175.28
Iron (mg)			5.81 ± 5.39

Abbreviations: MUAC, Mid-Upper Arm Circumference; HC, Head Circumference; HAZ, Height-for-Age z score; WAZ, Weight-for-Age z score; WHZ, Weight-for-Length z score. Categorical values are presented as frequency and percentage. Numerical values are presented as mean ± standard deviation with median, minimum and maximum data included.

compared to single malnutrition children (3,6,9–11). Apart from nutritional status, SCFA production is also influenced by dietary intake. The type, pattern, and content of food are important external factors that could interfere the composition and function of intestinal microbiota. Macronutrients such as carbohydrates, protein, fat, and fiber have an influence on microbiota metabolites formation. Previous study in Indonesia on children with malnutrition showed that dietary intake increased the number of major bacteria in the intestine which produced carbohydrate and fiber degrading enzymes, namely Bacteroides and Prevotella. It explained that the more of these bacterias exist, the SCFA produced also increase, especially acetate, propionate, and butyrate. This study finding is also in accordance with previous research that there is a relationship between fiber intake and propionic acid in malnutrition children. On the contrary, other study found that underweight subjects (BMI <18.5 kg/m^2) had reduced levels of propionic, butyric, and isovaleric acid. Different results may be due to the age of the subjects, namely 32 years in median and all underweight subjects were receiving a low-fiber diet, which may account for the low amount of SCFAs (10,12,13). Risk factors related to SCFA of malnourished children were analyzed in this study. Antibiotic usage showed significant correlation with SCFA profiles, spesifically propionic acid (p=0.033) and valeric acid (p=0.016). The number and dynamics of gut microbiota are influenced by several factors such as age, diet, geographical location, psychological situation, physical activity, and use of drugs. Antibiotics as antibacterial agents could damage the balance of intestinal microbiota. Previous study showed that antibiotic consumption in children could disrupt microbiota diversity, and it took approximately one month to restore to its normal composition. Although antibiotics reduce microbiota diversity, they increase overall microbial load. Research on seven days of betalactam therapy doubled fecal bacteria count yet increased the proportion of specific bacteria such as Bacteroides and Firmicutes. Dysbiosis caused by antibiotic usage could impede SCFA production.

Table 2. Correlation of SCFA and Nutritional Intake

Variables	Energy	Protein	Fat	Carbohydrate	Fibre	PUFA	Chol	Iron
Acetic acid (%)	0.551	0.599	0.103	0.639	0.183	0.534	0.887	0.377
Propionic acid (%)	0.436	0.797	0.545	0.702	**0.037 (r=0.330)**	0.866	0.517	0.092
Valeric acid (%)	0.054	0.189	0.239	0.055	0.125	0.124	0.409	0.850
Butyric acid (%)	0.841	0.605	0.612	0.268	0.925	0.762	0.517	0.679
Total SCFA (ng/ml)	0.877	0.225	0.760	0.737	0.599	0.063	0.595	0.224

Values are presented as p value from Spearman test result. Boldface indicates a statistically significant difference with p<0.05. Spearman test revealed significant correlation between fibre intake and propionic acid levels.

Table 3. Association of SCFA, Dietary Intake, and Malnutrition

Variables	Double malnutrition (mean ± SD)	Single malnutrition (mean ± SD)	p
Acetic acid	70.64 ± 8.64	60.13 ± 7.80	**0.00**
Propionic acid	17.52 ± 6.24	24.6 ± 12.16	**0.046**
Valeric acid	1.41 ± 1.50	1.81 ± 1.44	0.581
Butyric acid	6.68 ± 4.79	10.00 ± 7.04	0.106
Total SCFA	14.48 ± 7.05	13.87 ± 4.72	0.720
Energy (kcal)	1104.05 ± 163.23	1056.96 ± 213.58	0.180
Protein (gr)	25.77 ± 7.78	25.40 ± 8.10	0.615
Fat (gr)	42.36 ± 7.55	41.33 ± 7.97	0.655
Carbohydrate (gr)	155.80 ± 27.26	158.45 ± 33.83	0.780
Fibre (gr)	138.28 ± 473.83	800.47 ± 1738.60	0.293
PUFA (mg)	2.40 ± 1.94	2.74 ± 2.64	0.922
Cholesterol (mg)	156.49 ± 187.01	143.12 ± 159.73	0.933
Iron (mg)	5.67 ± 6.21	6.03 ± 3.83	0.246
Zinc (mg)	4.62 ± 1.23	11.38 ± 3.46	0.28
Vitamin A(ug)	1152.07±299.7	1050.34 ±238.2	0.51
Vitamin D (mg)	4.19 ±1.14	6.2 ± 1.54	0.11
Vitamin C (mg)	57.13 ± 17.04	130.9 ± 53.5	0.33

Values are presented as mean±standard deviation and p value from Mann-Whitney test result. Boldface indicates a statistically significant difference with P<0.05. Mann-Whitney test revealed significant difference of acetic acid in children with double and single malnutrition.

In children with malnutrition, exposure to antibiotics at young age is associated with immaturity and microbiome diversity, potentially leading to prolonged poor nutritional status. The immature microbiome participates in the long-term efficacy of drug and nutritional therapy. Study on malnourished and healthy Indonesian children showed that concentrations of dominant SCFAs such as acetate, propionate, and butyrate were lower in malnourished children compared to the control group. Malnourished children with low levels of SCFA in feces are susceptible to gastrointestinal infections such as diarrhea, intestinal inflammation, and systemic inflammation. Low SCFA affects energy availability in malnourished children because SCFA is related to the processes of gluconeogenesis, lipogenesis, and stimulation of catabolic metabolism, which worsens

Table 4. SCFA and Risk Factors of Malnourished Children

Variables		Acetic acid (mean ± SD)	p	Propionic acid (mean± SD)	p	Valeric acid (mean ± SD)	p	Butyric acid (mean ± SD)	p	Total SCFA (mean ± SD	p
Exclusive breastfeeding	No	65.30± 7.26	0.885	22.30± 10.03	0.219	1.38± 1.47	0.728	7.39± 3.50	0.954	13.15± 7.46	0.297
	Yes	67.37± 10.76		19.14± 9.16		1.65± 1.51		8.19± 6.78		14.78± 5.60	
Antibiotic usage	Yes	64.41± 9.04	0.138	22.94 10.19	**0.033**	1.07± 1.50	**0.016**	9.17± 7.54	0.433	14.12± 7.13	0.411
	No	68.39± 10.04		18.13± 8.50		1.93± 1.38		7.00± 4.22		14.34± 5.61	
Sick on admission	Yes	64.75± 7.17	0.416	21.85± 9.91	0.140	1.58± 1.49	0.734	8.35± 4.40	0.248	15.35± 7.45	0.386
	No	68.65± 11.59		18.50± 8.88		1.54± 1.55		7.50± 7.16		13.15± 4.61	
Congenital disease	Yes	69.0± 7.21	0.389	18.0± 4.44	0.390	1.81± 1.61	0.614	7.78± 4.99	0.833	16.22± 4.47	0.069
	No	66.03± 10.36		20.80± 10.43		1.49± 1.46		7.97± 6.19		13.68± 6.59	
Malabsorption	Yes	67.56± 10.32	0.599	17.06± 6.92	0.213	1.62± 1.61	0.989	10.50± 7.43	**0.042**	15.69± 7.99	0.489
	No	66.12± 9.47		22.25± 10.43		1.53± 1.42		6.20± 3.87		13.29± 4.63	

Values are presented as mean±standard deviation and p value from Mann-Whitney test result. Boldface indicates a statistically significant difference with P<0.05.

a) Mann-Whitney test revealed significant difference of malabsorption and butyric acid

b) Mann-Whitney test revealed significant difference of antibiotic usage with propionic acid and valeric acid

Table 5. SCFA and Fecal Analysis

Variables		Acetic acid (mean± SD)	p	Propionic acid (mean ± SD)	p	Valeric acid (mean ± SD)	p	Butyric acid (mean ± SD)	p	Total SCFA (mean ± SD	p
Mucus	Yes	70.67± 9.73	0.333	14.83± 7.28	0.074	0.78± 1.21	0.074	12.3± 11.76	0.371	16.83± 8.42	0.372
	No	66.0± 9.69		21.12± 9.55		1.70± 1.50		7.15± 3.97		13.79 ± 5.79	
Blood	Yes	-	-	-	-	-	-	-	-	-	-
	No	66.70± 9.72		20.18± 9.44		1.56± 1.48		7.92± 65.88		14.25 ± 6.22	
Fat	Yes	69.60±11.14	0.839	16.90± 6.10	0.253	1.47± 1.33	0.802	8.80± 5.73	0.442	16.70 ± 8.59	0.389
	No	65.73± 9.20		21.27± 10.17		1.59± 1.55		7.63± 5.99		13.43 ± 5.13	
Carbohydrate	Yes	67.0± 7.96	0.928	17.75± 7.37	0.982	1.77± 0.85	0.378	10.25± 3.77	0.182	16.75 ± 6.65	0.403
	No	66.67± 9.99		20.44± 9.69		1.54± 1.54		7.67± 6.05		13.97 ± 6.20	
Fibre	Yes	63.17± 7.46	**0.013**	22.78± 8.84	0.051	1.66± 1.34	0.287	7.72± 3.94	0.702	13.56 ± 5.26	0.693
	No	69.59± 10.53		18.04± 9.58		1.48± 1.61		8.09± 7.18		14.82 ± 6.97	
Erythrocytes	Yes	63.86± 7.36	0.508	22.38± 12.72	0.6	0.95± 0.95	0.1	10.63± 10.16	0.519	15.13 ± 6.17	0.722
	No	67.41±10.20		19.63± 8.61		1.72± 1.59		7.25± 4.23		14.03 ± 6.31	
Leukocytes	Yes	66.25± 9.88	0.879	21.00± 13.18	0.684	0.76± 1.37	**0.024**	9.75± 10.47	0.946	16.13± 5.84	0.242
	No	66.81± 9.83		19.97± 8.53		1.76± 1.46		7.47± 4.20		13.78 ± 6.31	
Occult blood	Yes	67.60±11.28	0.839	17.60± 12.71	0.067	1.29± 1.19	0.433	11.1± 9.06	0.145	17.20± 6.75	0.133
	No	66.40± 9.34		21.02± 8.17		1.65± 1.57		6.87± 4.05		13.27± 5.82	
Fungus	Yes	69.0± 8.49	0.443	16.36± 6.17	0.071	1.83± 1.63	0.619	10.0± 7.84	0.154	15.7± 6.66	0.280
	No	65.46±10.26		22.23± 10.33		1.42± 1.40		6.81± 4.27		13.46± 5.95	

Values are presented as mean±standard deviation and p value from Mann-Whitney test result. Boldface indicates a statistically significant difference with P<0.05.

a) Mann-Whitney test revealed significant difference of fecal fibre and acetic acid

b) Mann-Whitney test revealed significant difference of leukocytes count in feces with valeric acid

the general condition of children with malnutrition (14,15). On the fecal analysis, malabsorption showed significant difference with SCFA, namely butyric acid (p=0.042) and fibre count with acetic acid (p=0.013). As previously discussed, food intake is related to gut microbiota. Fiber intake is positively correlated with Bacteroides, which will increase SCFA production as shown in stool analysis. Conversely, other studies showed that Bacteroides counts decrease with increasing body mass index. Bacteroides deficiency results in inefficient energy metabolism, so that the macronutrients consumed, especially fiber will be excreted in the feces. In this study, leukocytes count in feces also had significant difference with valeric acid (p=0.024). High number of leukocytes in the feces is associated with an ongoing inflammatory or infectious process in the gastrointestinal tract. Malnourished children have a high susceptibility to infections in general. Moreover, with intestinal barrier dysfunction and alteration in microbiota, gastrointestinal infections are more likely to occur. Previous research also showed that high levels of leukocytes in feces were related to the microbiota profile, particularly increased presence of Bacteroides and Gemellaceae. This is related to low glucose consumption which may occur in malnourished children (16). Despite finding correlation between food intake and several risk factors with SCFA production, this study was unable to conclusively explain the association between variables. Future research should consider comparing the production of SCFA in children with normal nutritional status to their dietary consumption.

Acknowledgements: There are no other contributors who are not qualified on the author's list. Research is funded by all authors equally.

Funding: This study received grant from Faculty of Medicine Universitas Diponegoro.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Author Contribution: Conceptualization: RP, FAR, MSA, JP, MM; Data curation: RP, FAR, MSA, JP, MM; Formal analysis: RP, FAR, MSA, JP, MM; Methodology: RP, FAR, MSA, JP, MM; Project administration: RP, FAR, MSA, JP, MM; Writing-original draft: RP, FAR, MSA, JP, MM; Writing-review & editing: RP, FAR, MSA, JP, MM.

References

1. Becker P, Carney LN, Corkins MR, et al. Consensus statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: Indicators recommended for the identification and documentation of pediatric malnutrition (undernutrition). Nutr Clin Pract. 2015;30(1):147–61. doi:10.1177/0884533614557642
2. The Joint Child Malnutrition Estimates (JME). Levels and trends in child malnutrition: UNICEF/WHO/World Bank Group Joint Child Malnutrition Estimates: Key Findings of the 2023 Edition. UNICEF, World Health Organ World Bank Gr. 2023;24(2):32.
3. Iddrisu I, Monteagudo-Mera A, Poveda C, , et al. Malnutrition and gut microbiota in children. Nutrients. 2021;13(8):1–21. doi:10.3390/nu13082727
4. Selimoglu MA, Kansu A, Aydogdu S, et al. Nutritional Support in Malnourished Children With Compromised Gastrointestinal Function: Utility of Peptide-Based Enteral Therapy. Front Pediatr. 2021 Jun 7;9:610275. doi: 10.3389/fped.2021.610275.
5. Singh R, Zogg H, Wei L, et al. Gut Microbial Dysbiosis in the Pathogenesis of Gastrointestinal Dysmotility and Metabolic Disorders. J Neurogastroenterol Motil. 2021 Jan 30;27(1):19-34. doi: 10.5056/jnm20149.
6. Afzaal M, Saeed F, Shah YA, et al. Human gut microbiota in health and disease: Unveiling the relationship. Front Microbiol. 2022 Sep 26;13:999001. doi: 10.3389/fmicb.2022.999001.
7. World Health Organization. Guideline: assessing and managing children at primary health-care facilities to prevent overweight and obesity in the context of the double burden of malnutrition. Updates for the Integrated Management of Childhood Illness (IMCI). Geneva: World Health Organization; 2017. Licence:CC BY-NC-SA 3.0 IGO
8. Casadei K, Kiel J. Anthropometric Measurement. [Updated 2022 Sep 26]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK537315/.
9. Fusco W, Lorenzo MB, Cintoni M, et al. Short-Chain Fatty-Acid-producing bacteria: Key components of the human gut microbiota. Nutrients. 2023;15(9). doi: 10.3390/nu15092211.
10. Gatya M, Fibri DLN, Utami T, Suroto DA, Rahayu ES. Gut Microbiota Composition in Undernourished Children

Associated with Diet and Sociodemographic Factors: A Case-Control Study in Indonesia. Microorganisms. 2022 Aug 30;10(9):1748. doi: 10.3390/microorganisms10091748.
11. Jones HJ, Bourke CD, Swann JR, Robertson RC. Malnourished Microbes: Host-Microbiome Interactions in Child Undernutrition. Annu Rev Nutr. 2023 Aug 21;43:327-353. doi: 10.1146/annurev-nutr-061121-091234.
12. Ecklu-Mensah G, Gilbert J, Devkota S. Dietary selection pressures and their ompact on the gut microbiome. Cell Mol Gastroenterol Hepatol. 2022;13(1):7-18. doi: 10.1016/j.jcmgh.2021.07.009.
13. Dąbek-Drobny A, Kaczmarczyk O, Woźniakiewicz M, et al. Association between fecal Short-Chain Fatty Acid Levels, diet, and Body Mass Index in patients with Inflammatory Bowel Disease. Biology (Basel). 2022 Jan 10;11(1):108. doi: 10.3390/biology11010108.
14. Yang J, Wu J, Li Y, et al. Gut bacteria formation and influencing factors. FEMS Microbiol Ecol. 2021;97(4):1–10. doi: 10.1093/femsec/fiab043.
15. Zoghi S, Sadeghpour Heravi F, Nikniaz Z, et al. Gut microbiota and childhood malnutrition: Understanding the link and exploring therapeutic interventions. Eng Life Sci. 2023;(April 2023):1–23.
16. Del Chierico, F., Manco, M., Gardini, S. et al. Fecal microbiota signatures of insulin resistance, inflammation, and metabolic syndrome in youth with obesity: a pilot study. Acta Diabetol 58, 1009–1022 (2021). doi: 10.1007/s00592-020-01669-4

Correspondence:
Received: 11 March 2025
Accepted: 3 June 2025
Rina Pratiwi, MD
Department of Child Health, Faculty of Medicine Universitas Diponegoro, Kariadi General Hospital
Semarang, Indonesia
E-mail: rinapratiwi@fk.undip.ac.id
ORCID: 0000-0002-8756-5615