

Original Article



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Correspondence to

Yoo Kyoung Park

Department of Medical Nutrition, Graduate School of East-West Medical Science, Kyung Hee University, 1732 Deogyong-daero, Giheung-gu, Yongin 17104, Korea.
Email: ypark@khu.ac.kr

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ORCID iDs

Hyeji Yoon

<https://orcid.org/0000-0003-4570-7408>

Hyoung su Park

<https://orcid.org/0000-0001-7205-1366>

Xiangxue An

<https://orcid.org/0000-0003-4604-0828>

Seok Jun Park

<https://orcid.org/0000-0002-5407-0149>

Gwang Woong Go

<https://orcid.org/0000-0002-3848-8705>

Hyunjung Kim

<https://orcid.org/0000-0002-9802-4814>

Hyesoon Lee

<https://orcid.org/0000-0003-0814-7691>

Mee Na Kim

<https://orcid.org/0000-0003-1565-4296>

<https://e-cnr.org>

Study on the Improvement of Health and Nutrition Status After a 12-week Protein-Rich Supplementation Regimen in Children and Adolescents With Brain Lesions Disorder

Hyeji Yoon ¹, Hyoung su Park ¹, Xiangxue An ¹, Seok Jun Park ¹, Gwang Woong Go ², Hyunjung Kim ³, Hyesoon Lee ⁴, Mee Na Kim ⁵, Yoo Kyoung Park ⁶

¹R&D Unit, Mael Health Nutrition Co., Ltd, Pyeongtaek 17714, Korea

²Department of Food and Nutrition, Hanyang University, Seoul 04763, Korea

³Happy Link, Incheon 21524, Korea

⁴Department of Child Care, Yuhan University, Bucheon 14780, Korea

⁵Korea Institute of Child Education, Bucheon 14479, Korea

⁶Department of Medical Nutrition, Graduate School of East-West Medical Science, Kyung Hee University, Yongin 17104, Korea

ABSTRACT

Through a survey on dietary intake of children and adolescents with brain lesions, the present study aimed to analyze the current status of nutrient intake and examine the effect of high-protein nutrient drink on their nutritional and muscle statuses. The study participants were 90 juvenile participants aged 8–19 years, with brain lesions. The participants were provided with a protein nutrient drink for 12 weeks and a questionnaire survey on dietary intake was performed to analyze the level of nutrient intake before and after ingestion. The physical measurements were taken to determine the improvements in nutrient and muscle statuses. The results showed that, before the intake of protein nutrient drink as a supplement, the participants exhibited lower height, weight, and body mass index than those of the standard levels of healthy individuals, and the level of nutrient intake through diet was lower than those of the required and recommended levels of nutrient intake for Koreans. Conversely, after the intake of protein nutrient drink for 12 weeks, the level of nutrient intake and physical statuses such as weight showed significant improvements. In addition, the muscle status had undergone approximately 10% of change during the intervention with no significant difference. Thus, to ensure an adequate level of nutrient supply to children and adolescents with brain lesions, there is an urgent need to develop a guideline of nutrient intake. The findings in this study are expected to serve as the basic data for such guidelines.

Keywords: Brain; Children with disability; Nutritional status; Proteins; Skeletal muscle

INTRODUCTION

According to the National Survey of Persons with Disabilities conducted by the Ministry of Health and Welfare, the number of persons with disabilities in South Korea was

Yoo Kyoung Park 
<https://orcid.org/0000-0002-8536-0835>

Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

Conceptualization: Park YK, Kim H, Lee H, Kim MN, Park SJ, Park HS; Investigation: An X, Yoon H, Park HS; Methodology: Park YK, Kin HJ, Lee H, Kim MN, Park HS; Project administration: Park SJ, Park YK; Software: Yoon H, An X; Supervision: Park YK, Park SJ, Go GW; Validation: Park YK, Go GW; Writing - original draft: Yoon H, Park HS; Writing - review & editing: Park YK, Go GW.

approximately 1,339,496 in 2000 and 2,580,340 in 2017, showing an 51.9% increase in the past decade. Among them, the number of children and adolescents aged below or equal to 17 was 85,000 thus accounting for 3.3% of the total survey population. Although the number of children and adolescents with disabilities is small in view of the total number of persons with disabilities, when considering special requirements regarding their development, the number appears significantly high.

Numerous studies reported that at least 40% of the children with disabilities had low nutrient intake that led to poor growth with a state of malnutrition [1]. Other studies have reported that 25% had an inappropriate diet and 15%–25% fell below the 5 percentiles of weight for length ratio [2]. As such, children with disabilities had diverse nutrient problems such as poor growth, anemia, or constipation [1] attributed to the low levels of use and absorption of nutrients resulting from congenital metabolic disorders, as well as malnutrition and dysfunction related to diet caused by the administration of drugs such as seizure suppressants [3,4]. Notably, for most children with disabilities, 30%–50% had a problem related to food intake [5] with the highest severity displayed by the children with cerebral palsy [1]. In a study comparing the dietary habits and food intake behaviors between children with disabilities and the control, the food they preferred were different from that preferred by children without disabilities [6] in shape and size of food [7]. Notably, the cause of malnutrition in children and adolescents with brain lesions is orofacial dyskinesia due to muscle strain and rigidity caused by a congenital defect that makes food intake difficult [8]. Juvenile patients with brain lesions causing cerebral palsy have low weight and height compared to children and adolescents with other disabilities [4,9-11]. The most significant cause of these discrepancies is nutrient deficiency and reduced muscle mass [4,9,12].

The recommended level of protein intake in children with disability is approximately 2.0 g/kg per day [13]. The influencing factors in the estimation of protein requirements in certain age groups or specific participants are the supplied food types and digestibility. The supplied food types determine the amino acid constituents and essential amino acid contents. High contents of essential amino acids are found in animal proteins and soybean proteins that are categorized as high-quality proteins based on high digestibility, while plant proteins show low utility in the body due to the presence of limiting amino acids, as well as similarly low digestibility [14]. The protein quality is evaluated using a chemical or a biological method. The chemical method is mainly based on the amino acid score (AS), in accordance with the reference proteins of the ideal standard contents of essential amino acids that represent the amino acid requirements estimated for the protein requirements in the human body. The biological method is the chemical method reflecting the rates of digestion and absorption such as the Protein Digestibility Corrected Amino Acid Score (PDCAAS) and the Digestible Indispensable Amino Acid Score (DIAAS) [15]. **Figure 1** shows the amino acid values for each protein as an example. In South Korea, the intake of animal proteins is below or equal to 50%, a relatively low level compared to that in the western countries, while the intake of plant proteins is high, which predicts a low level of protein utilization efficiency [16]. Therefore, it is necessary to provide high-quality protein sources to children and adolescents with disabilities showing inadequate protein intake.

Children and adolescents with disabilities (brain lesions and physical disabilities that pose a difficulty in movement) spend most of their time at home or hospital with minimum outdoor activities, which prevents vitamin D synthesis from sunlight, and the vitamin D required by the body should be obtained via food intake. Moreover, for patients with spastic quadriplegic

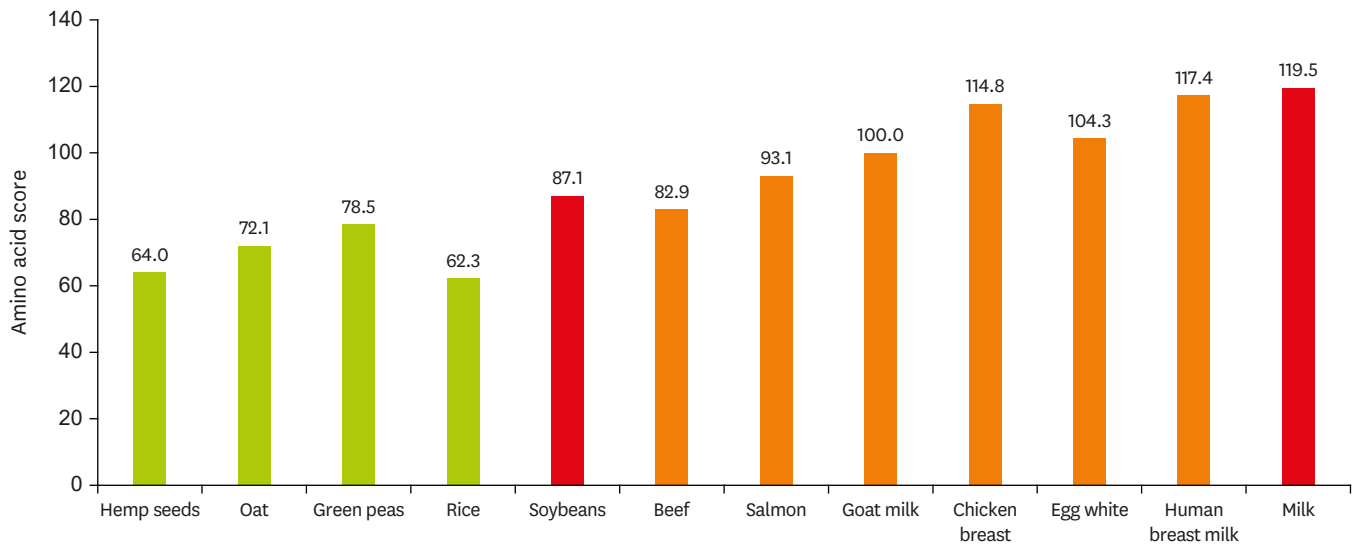


Figure 1. Protein amino acid score. Amino acid score calculated as: mg of Amino Acid in 1 g of Test Protein/mg of Amino Acid in Reference Pattern × 100. Amino acid content data from U.S. Department of Agriculture food data central. Amino acid in reference pattern data from Korean health functional food standards and specifications.

cerebral palsy, the intake of food produced for enteral nutrition could destroy the balance of nutrients and cause deficiency of micronutrients or vitamins [17-19]. Thus, to prevent micronutrient or vitamin deficiency, continuous assessment and monitoring are essential.

The nutrient status in childhood may have a significant impact on the physical and psychological developments in a person's adult life. The intake of nutrients via diet is essential in physical composition and healthy performance of physical functions [20].

Thus, overseas countries have conducted various studies on the nutritional characteristics related to chronic diseases, cognitive, and developmental disorders, congenital metabolic disorders or genetic disorders, and the role of each disorder in terms of nutrition to the effect that they have established clinical guidelines [21]. However, despite the highlighted importance of nutrient management in children and adolescents with disabilities, there is a general lack of studies regarding nutrient management in South Korea and guidelines are yet to be established.

This study investigated the current status of nutrient intake in children and adolescents with brain lesions living at home in the area of Incheon, South Korea. And further identified the effects of the intervention of a 12-week supply of protein nutrient drink on the improvements in health and nutrient statuses as well as in muscle status. The aim was to provide basic data for the development of guidelines regarding nutrient management for children and adolescents with disabilities.

MATERIALS AND METHODS

Study participants and duration of study

The participants in this study were recruited through an advertisement for the members of nongovernmental organization (NGO) group, Happy Link to the juvenile patients with severe

disabilities who reside in Incheon, South Korea. As there were concerns regarding reduced comprehension or judgment among the recruited children and adolescents with disabilities, an immediate family or cohabitant (legal representative) was given detailed explanations on the experiment, and signed consent forms were obtained. Among the recruited participants, those unable to perform oral intake, those who are allergic to nuts or dairy products, such as milk, and those on diet control as part of disease management, were excluded. The finally selected participants were children and adolescents with disabilities who were aged 8–19 years, capable of oral intake, and able to drink commercial beverages.

Ninety participants were enrolled in the study, and were provided with a protein nutrient drink for 12 weeks. The nutrient and health statuses before and after the intake of the protein nutrient drink were determined to investigate the level of improvements. This study was conducted with the approval of the Institutional Review Board (IRB; approval number: KHGIRB-20-471).

Demographics

For the demographic data of the participants such as height, weight, date of birth, sex, disability, and treatment, the parents or guardians were requested to complete the questionnaire.

Intake of protein nutrient drink

The amount of protein nutrient drink (Selecs product 125 mL, protein 8 g ; animal protein 6: plant protein 4, leucine 1,000 mg, vitamin D 10 µg, calcium 290 mg; Maeil Health & Nutrition Co., Ltd., Seoul, Korea) provided to the participants was calculated based on the recommended nutrient intake for proteins, calcium, vitamin D, and leucine, according to the Standard Nutrient Intake for Koreans (2020); one pack of drink a day was provided to the participants aged 8–11 years and two packs a day were provided to the participants aged 12–19 years (Table 1).

Survey of dietary intake

The 24-hour dietary recall method was used to conduct the survey of dietary intake. The parents or guardians were requested to record the diet in terms of the type and amount of all food and products consumed by the participants in three consecutive days before (week 0) and after (week 12) the intake of protein nutrient drink. The recording log had separate categories for breakfast, morning snack, lunch, afternoon snack, dinner, and others, in

Table 1. Nutrient of RNI and protein nutrition drinks

Nutrients	RNI* (Age 9–11)		RNI (Age 12–14)		RNI (Age 15–18)		Protein drink	
	Male	Female	Male	Female	Male	Female	125 mL (1 serving)	250 mL (2 serving)
Protein (g)	50	45	60	55	65	55	8	16
Vitamin A (µgRE)	600	550	750	650	850	650	250	500
Vitamin D [†] (µg)	5	5	10	10	10	10	10	20
Vitamin B ₁ (mg)	0.9	0.9	1.1	1.1	1.3	1.1	0.6	1.2
Vitamin B ₂ (mg)	1.1	1.0	1.5	1.1	1.4	1.1	0.45	0.9
Niacin (mgNE)	11	12	15	15	17	14	3.2	6.4
Vitamin B ₆ (mg)	1.1	1.1	1.5	1.4	1.5	1.4	1.0	2.0
Folate (µg)	300	300	360	360	400	400	85	170
Pantothenic acid (mg)	4	4	5	5	5	5	1.4	2.8
Calcium (mg)	800	800	1,000	900	900	800	290	580
Iron (mg)	11	10	14	16	14	14	5	10
Zinc (mg)	8	10	8	16	10	14	6	12
Leucine (mg)	1,900	1,800	2,700	2,400	3,200	2,400	1,000	2,000

RNI, recommended nutrient intake

*Nutrients to the recommended intake in the 2020 Dietary Reference Intakes for Koreans; [†]Adequate intake.

which the details of the food name and amount of intake could be recorded as thoroughly as possible to allow the analysis of the current dietary intake of the participants. The recording was performed before and after the intake of protein nutrient drink, and the CAN-Pro (ver. 5.0, 2015; The Korean Nutrition Society, Seoul, Korea) was used to analyze the changes in current nutrient intake as the mean of the recorded intake of three consecutive days.

For the assessment of intake of each nutrient, the measured intake was compared with the recommended nutrient intake (RNI) suggested in the Standard Nutrient Intake for Koreans (2020). The level of energy was tested based on the estimated energy requirement (EER) and the levels of vitamin D and pantothenic acid were tested based on the adequate intake (AI) [22].

Physical measurements

The height and weight were measured, based on which the body mass index (BMI) was calculated to examine the level of growth of the participants before and after the intake of protein nutrient drink. As it was difficult for children with cerebral palsy to stand independently preventing an accurate height measurement, the children were guided to lie down on a flat surface and the height was measured using a tape. The weight was measured in the unit of kg, and when the children had difficulty standing on the scale independently, the parents or guardians were requested to hold the children and stand on the scale, after which the weight of the parents or guardians was subtracted from the measured weight to obtain the weight of the children. The physical measurements of the participants were then compared with the standard height, weight, and BMI of children in the same age group presented in the growth chart created in 2017 by the Korea Disease Control and Prevention Agency. For adolescents aged ≥ 12 years, significant differences in physical measurements were observed between those aged 12–14 years and those aged 15–19 years therefore making a comparison between 3 age groups: 8–11, 12–14, and 15–19 years. In addition, to examine the muscle status, the skeletal muscle mass, fat free mass and body fat mass were measured via the bioelectric impedance analysis (InBody S10; InBody Co., Seoul, Korea). The InBody device, likewise, allowed measurements while the participants were lying down on a surface. For the skeletal muscle mass, while the muscles in the human body are broadly categorized into the cardiac, visceral, and skeletal muscles, the InBody device defined the skeletal muscle mass as the number of voluntary muscles that enable body movements. The fat free mass was the muscle mass excluding the body fat mass, as measured by weight; that is, the amount of minerals, water, and bones, excluding fat. The body fat mass was the total amount of lipids that could be extracted from the adipose and other tissues [23].

Statistical analysis

All data collected in this study were analyzed using the SPSS® Package Program version 22 (IBM Corp., Armonk, NY, USA). The results obtained in the survey of dietary intake are presented as mean and standard deviation. To test the significance in the comparison between specific values and standard values of physical traits of participants, the independent t-test was performed. To compare the times before and after the intake of protein nutrient drinks, the paired t-test was performed. The level of significance was set to $p < 0.05$.

Table 2. General characteristics of the participants

Variable	Total (n = 90)	8–11 yr (n = 15)	12–14 yr (n = 32)	15–19 yr (n = 43)
Sex				
Male (%)	55 (61.1)	11 (73.3)	19 (59.4)	25 (56.8)
Female (%)	35 (38.9)	4 (26.7)	13 (40.6)	18 (43.2)
Type of disability				
Cerebral lesion disorder grade 1–3	66 (73.3)	11 (73.3)	23 (71.9)	32 (78.4)
Multiple disorder (Brain lesions + Other disorders)	18 (20.0)	4 (26.7)	7 (21.9)	7 (10.8)
Physical disability	4 (4.4)		1 (3.1)	3 (8.1)
Physical disability + Intellectual disability	2 (2.2)		1 (3.1)	1 (2.7)

RESULTS

General characteristics of participants and physical measurements

For sex, there were 55 males (61.1%) and 35 females (38.9%). The age distribution was 8–11 years (n = 15, 16.7%), 12–14 years (n = 32, 35.6%) and 15–19 years (n = 43, 47.8%). For the type of disability, brain lesion was the most frequent type (n = 66, 73.3%), followed by brain lesion with other disorders (cognitive, auditory, or visual impairment; n = 18, 20.0%), cognitive disorder (n = 4, 4.4%), and physical and cognitive disorders (n = 2, 2.2%) (**Table 2**).

Furthermore, the physical measurements of the participants before the intake of protein nutrient drink (**Table 3**) were compared with the standard height, weight, and BMI of children in the same age group presented in the growth chart created in 2017 by the Korea Disease Control and Prevention Agency. Compared to the standard physical measurements of children in the same age group, the male children with brain lesions aged 8–11 years showed significantly lower weight (p < 0.01), height, and BMI (p < 0.05). The female children had significantly lower height than the standard height (p < 0.05), but the weight and BMI did not show significant differences from the standard values. The male children aged 12–14 years showed significantly lower weight and height than the standard values (p < 0.001) with significantly lower BMI values (p < 0.01). The female children, likewise, showed significantly lower values than the standard values (p < 0.01). The male and female children aged ≥ 15 years showed significantly lower weight and height than the standard values (p < 0.001) with a significantly lower BMI (p < 0.01).

Current nutrient intake of children with brain lesions assessed through dietary survey

From the data of a dietary survey of the 90 children in this study, the cases with < 80% compliance for the intake of protein nutrient drink were viewed as non-compliance and only

Table 3. Anthropometric measurement of disabled children and non-disabled children

Variable	8–11 yr (n = 15)		12–14 yr (n = 32)		15–19 yr (n = 43)	
	Non-disabled [†]	Disabled	Non-disabled	Disabled	Non-disabled	Disabled
Weight (kg)						
Male	35.66 ± 5.19	24.93 ± 10.65**	53.07 ± 4.40	35.39 ± 12.06***	64.71 ± 2.31	45.51 ± 16.84***
Female	34.51 ± 5.09	30.50 ± 6.81	48.73 ± 2.62	36.00 ± 10.09**	53.79 ± 0.41	35.25 ± 13.79***
Height (cm)						
Male	138.88 ± 6.71	127.73 ± 14.37*	161.16 ± 5.43	142.32 ± 12.44***	172.36 ± 1.46	155.20 ± 13.71***
Female	138.93 ± 7.48	128.75 ± 11.21*	156.61 ± 2.34	148.26 ± 8.94**	160.29 ± 0.42	140.69 ± 13.77***
BMI (kg/m ²)						
Male	18.35 ± 0.86	14.64 ± 3.38*	20.50 ± 0.40	17.15 ± 3.93**	21.92 ± 0.43	18.26 ± 4.93**
Female	17.80 ± 0.75	18.27 ± 2.14	19.98 ± 0.49	16.18 ± 3.75**	21.01 ± 0.08	17.17 ± 4.95**

Values are presented as mean ± standard deviation.

Significantly different between non-disabled and disabled intervention by independent t-test: *p < 0.05, **p < 0.01, ***p < 0.001.

[†]Non-disabled: normal children and adolescents, data from Korea Centers for Disease Control and Prevention's 2017 growth chart of children and adolescents.

Table 4. %RNI* of nutrient intake for disabled children

Variable	Intervention (n = 46)		8–11 yr (n = 9)		12–19 yr (n = 37)	
	0 weeks	12 weeks	0 weeks	12 weeks	0 weeks	12 weeks
Energy [†] (%)	53.22 ± 16.90	53.41 ± 14.22	57.40 ± 23.45	53.72 ± 20.02	52.21 ± 15.15	53.34 ± 12.79
Protein (%)	76.31 ± 28.65	72.87 ± 24.93	82.66 ± 45.88	76.30 ± 31.49	74.77 ± 23.37	72.04 ± 23.51
Vitamin A (%)	38.76 ± 21.84	40.91 ± 24.73	38.88 ± 24.79	40.90 ± 36.29	38.73 ± 21.44	40.91 ± 21.71
Vitamin B ₁ (%)	102.89 ± 43.00	98.28 ± 39.12	107.63 ± 53.57	95.92 ± 33.43	101.74 ± 40.82	98.86 ± 40.78
Vitamin B ₂ (%)	83.49 ± 43.40	76.72 ± 33.67	98.73 ± 72.12	85.90 ± 42.82	79.79 ± 33.56	74.49 ± 31.36
Niacin (%)	50.78 ± 18.36	49.44 ± 19.73	48.75 ± 18.25	55.97 ± 30.49	51.27 ± 18.61	47.85 ± 16.33
Vitamin B ₆ (%)	78.91 ± 33.06	74.44 ± 34.82	81.05 ± 24.51	85.67 ± 27.82	48.39 ± 35.09	71.71 ± 36.12
Pantothenic acid [‡] (%)	73.55 ± 34.22	70.42 ± 21.30	91.14 ± 59.58	71.11 ± 33.64	69.27 ± 24.05	70.26 ± 17.77
Folate (%)	80.95 ± 32.02	78.17 ± 22.24	82.72 ± 41.98	74.94 ± 25.69	80.52 ± 29.82	78.95 ± 21.64
Vitamin D [‡] (%)	39.31 ± 52.95	26.86 ± 24.63	82.56 ± 106.62	40.59 ± 40.20	28.79 ± 19.92	23.52 ± 18.46
Calcium (%)	47.57 ± 33.59	37.64 ± 17.23	61.71 ± 66.51	49.98 ± 26.24	44.13 ± 19.10	37.12 ± 13.59
Magnesium (%)	22.17 ± 11.95	22.93 ± 12.40	28.26 ± 18.84	31.30 ± 20.27	20.68 ± 9.39	20.90 ± 8.90
Iron (%)	70.99 ± 32.64	74.70 ± 27.98	74.05 ± 36.30	72.39 ± 30.67	70.25 ± 32.18	75.26 ± 27.71
Zinc (%)	64.16 ± 29.18	71.98 ± 23.01	74.02 ± 32.05	74.41 ± 23.97	61.76 ± 28.39	71.39 ± 23.08
Leucine (%)	96.59 ± 57.47	84.52 ± 38.39	119.18 ± 96.73	104.33 ± 67.49	91.09 ± 43.47	79.70 ± 26.60

Values are presented as mean ± standard deviation.

%RNI, percent ratio of energy and nutrients to the recommended intake in the 2020 Dietary Reference Intakes for Koreans.

*%RNI = Actual Intake/Recommended Nutrient Intake.

[†]%EER = (Actual Intake/Estimated Energy Requirement) × 100.

[‡]%AI = (Actual Intake/Adequate Intake) × 100.

the cases of ≥ 80% compliance (n = 46) were analyzed for the level of nutrient intake. The daily mean nutrient intake per age group compared to the recommended nutrient intake (%RNI), the estimated energy requirement (%EER), and the adequate intake (%AI) are presented in **Table 4**. For the analyzed participants (n = 46), the comparison per nutrient in all age groups showed that, except for vitamin B₁, the nutrient intake was below 100% of the recommended levels. Notably, the calorie intake was very low, < 60% of the EER. The protein intake was < 80% of the RNI. The intake of vitamin D was also < 50% of the RNI.

For each age group, the participants aged 8–11 years showed < 75% of the RNI for vitamin A, niacin, calcium, magnesium, iron, and zinc, and those aged 12–19 years showed < 75% of the RNI for proteins, vitamin A, niacin, vitamin B₆, calcium, magnesium, and zinc.

Changes in the nutrient intake, physical measurements, and body composition of children with brain lesions after the 12-week intake of protein nutrient drink

Changes in nutrient intake

The changes in nutrient intake before and after the 12-week intake of protein nutrient drink are presented in **Table 5**. Compared to the %RNI, %EER, and %AI for Koreans, all age groups showed a significant increase in the intake of all nutrients except magnesium (before intake: 22.17% ± 11.95%, after intake: 23.48% ± 12.03%). The result values were also ≥ 100% of the %RNI (except niacin and magnesium) and %EER (except pantothenic acid and vitamin D).

Changes in physical measurements

The changes in physical measurements before and after the intake of protein nutrient drinks are presented in **Table 6**. In a study on intervention, the compliance to the intake of the provided food is generally set to ≥ 80%. As a result, the weight and height of all 90 participants showed a significant increase after the intake of the nutrient drink (p < 0.001) with a significant increase in BMI (p < 0.01). The participants with ≥ 80% compliance (n = 46) also showed a significant increase in weight and height but no significant difference in BMI after the intake of the nutrient drink.

Table 5. Change in %RNI[†] before and after intake nutrition beverage

Variable	Intervention (n = 46)		8–11 yr (n = 9)		12–19 yr (n = 37)	
	Before	After	Before	After	Before	After
Energy [‡] (%)	53.22 ± 16.90	64.28 ± 14.39**	57.40 ± 23.45	60.64 ± 20.08	52.21 ± 15.15	65.16 ± 12.85***
Protein (%)	76.31 ± 28.65	100.31 ± 22.78***	82.66 ± 45.88	94.54 ± 32.20	74.77 ± 23.37	101.71 ± 20.20***
Vitamin A (%)	38.76 ± 21.84	107.00 ± 26.96***	38.88 ± 24.79	83.98 ± 36.09*	38.73 ± 21.44	112.61 ± 21.31***
Vitamin B ₁ (%)	102.89 ± 43.00	197.05 ± 40.15***	107.63 ± 53.57	162.58 ± 33.43	101.74 ± 40.82	205.43 ± 37.39***
Vitamin B ₂ (%)	83.49 ± 43.40	144.09 ± 33.38***	98.73 ± 72.12	129.09 ± 41.77	79.79 ± 33.56	147.74 ± 30.58***
Niacin (%)	50.78 ± 18.36	89.51 ± 17.10***	48.75 ± 18.25	83.01 ± 28.15*	51.27 ± 18.61	91.09 ± 13.28***
Vitamin B ₆ (%)	78.91 ± 33.06	204.44 ± 38.73***	81.05 ± 24.51	176.58 ± 27.82***	48.39 ± 35.09	211.21 ± 38.23***
Pantothenic acid [§] (%)	73.55 ± 34.22	122.32 ± 22.78***	91.14 ± 59.58	106.11 ± 33.64	69.27 ± 24.05	126.26 ± 17.77***
Folate (%)	80.95 ± 32.02	119.54 ± 23.76***	82.72 ± 41.98	103.27 ± 25.69	80.52 ± 29.82	123.49 ± 21.83***
Vitamin D [§] (%)	39.31 ± 52.95	226.86 ± 24.63***	82.56 ± 106.62	240.59 ± 40.20**	28.79 ± 19.92	223.52 ± 18.46***
Calcium (%)	47.57 ± 33.59	100.64 ± 18.25***	61.71 ± 66.51	86.23 ± 26.24	44.13 ± 19.10	104.15 ± 14.10***
Magnesium (%)	22.17 ± 11.95	23.48 ± 12.03	28.26 ± 18.84	31.30 ± 20.27	20.68 ± 9.39	21.58 ± 8.40
Iron (%)	70.99 ± 32.64	141.92 ± 37.14***	74.05 ± 36.30	120.90 ± 34.39*	70.25 ± 32.18	147.03 ± 36.39***
Zinc (%)	64.16 ± 29.18	165.08 ± 48.16***	74.02 ± 32.05	142.38 ± 24.47**	61.76 ± 28.39	170.61 ± 24.04***
Leucine (%)	96.59 ± 57.47	159.55 ± 36.33***	119.18 ± 96.73	158.75 ± 68.02	91.09 ± 43.47	159.75 ± 24.93***

Values are presented as mean ± standard deviation.

%RNI, percent ratio of energy and nutrients to the recommended intake in the 2020 Dietary Reference Intakes for Koreans.

Significantly different between before and after intervention by paired t-test: *p < 0.05, **p < 0.01, ***p < 0.001.

[†]%RNI = Actual Intake/Recommended Nutrient Intake.

[‡]%EER = (Actual Intake/Estimated Energy Requirement) × 100.

[§]%AI = (Actual Intake/Adequate Intake) × 100.

Table 6. Change of anthropometric measurement during 12-week study period

Variable	Intervention (n = 90)		≥ 80% compliance (n = 46)	
	Before	After	Before	After
Weight (kg)	36.77 ± 14.55	38.13 ± 14.57***	39.18 ± 14.83	40.46 ± 14.69**
Height (cm)	144.04 ± 15.50	145.28 ± 15.16***	144.46 ± 14.99	146.20 ± 14.34***
Body mass index (kg/m ²)	17.07 ± 4.36	17.41 ± 4.34**	18.18 ± 4.39	18.35 ± 4.39

Values are presented as mean ± standard deviation.

Significantly different between before and after intervention by paired t-test: *p < 0.05, **p < 0.01, ***p < 0.001.

Table 7. Muscle health and physical performance changes during 12-week study period

Variable	Disabled (n = 7)		
	Before	After	Change ratio (%) [*]
Skeletal muscle mass (kg)	15.99 ± 5.02	17.84 ± 4.52	▲11.57
Fat free mass (kg)	30.54 ± 8.42	33.80 ± 7.33	▲10.67
Body fat mass (kg)	10.31 ± 7.60	10.24 ± 5.40	▼0.68

Values are presented as mean ± standard deviation.

*Change ratio (%) = {(After Measurement Value – Before Measurement Value)/Before Measurement Value} × 100
Calculated by Mean Value.

Changes in body composition

The changes in body composition before and after the intake of protein nutrient drinks are presented in **Table 7**. The results of skeletal muscle mass, fat free mass, and body fat mass are shown. Although 30 participants had agreed to the InBody measurements to examine the muscle status, the results could be obtained for only seven participants owing to absence on the day of measurements or serious health issues, such as edema. The body composition after the intake of the protein nutrient drink showed the following changes: increase in skeletal muscle mass and fat free mass by 11.57%, and 10.67%, respectively, and a decrease in body fat mass by 0.68%. However, between the times before and after the intake of the nutrient drink, these changes were not statistically significant.

DISCUSSION

This study was conducted to investigate the current status of dietary intake in children and adolescents with brain lesions residing in Incheon, South Korea, with an aim to analyze the problems in their diet and identify the effects of the 12-week intake of a protein nutrient drink (containing multiple nutrients from proteins, vitamin D, to calcium, minerals and vitamin.) on the improvements of nutrient and muscle statuses via continuous high-protein nutrient supply.

Most studies on children with brain lesions in South Korea had been conducted on children in special-education schools or care centers to restrict the age of the children to ≤ 12 years. The studies had also focused more on the current nutrient intake than on nutrient management [24]. The children at care centers received nutrient management in part as they were provided with one meal a day upon their visit to the center. However, in this study the age range was extended to include adolescents who have greater demand for nutrients due to rapid physical development, which was in contrast to most previous studies conducted in South Korea [25].

The participants usually receive at least one meal a day during the visit to the institution. However, the participants were not allowed to visit the institution as this study was conducted after the outbreak of COVID-19 and therefore the current nutrient intake at home was examined instead.

The age range of the participants in this study was 8–19 years, and 93.3% of the participants had brain lesions or brain lesion combined with other disorders. For assessing physical characteristics, height, weight, and BMI of the participants in this study were compared with the standard values in the growth chart for children and adolescents. The result showed that, except for the weight and BMI of females aged 8–11 years, the level of physical development was low across all age groups. The survey of dietary intake to analyze the current nutrient intake of the participants showed that, except vitamin B₁, the levels of nutrients in all age groups did not reach 100% of the recommended levels. Notably, the intake of proteins as essential nutrients in the growth and the increase in muscle mass during childhood and adolescence [13] and in the production of antibodies for immunity, enzymes and hormones, fell below approximately 80% to imply inadequate intake.

The levels of calcium and vitamin D intake with a critical role in muscle health besides proteins were analyzed, and the results showed that the intake of calcium was approximately < 60% of the recommended intake and the intake of vitamin D was approximately < 50% of the recommended intake, with the exception of participants aged 8–11 years at week 0 implying more inadequacy than the intake of proteins. Calcium is involved in muscle contraction and relaxation [26] and vitamin D facilitates protein synthesis by promoting muscle synthesis and calcium absorption to increase the intracellular ATP concentration [27]. Thus, besides proteins, the intake of vitamin D and calcium are important for the muscle health of children with brain lesions. In addition, the intake of magnesium was approximately < 40% of the RNI to indicate the lowest level of intake. Magnesium plays a role as a component in bones and teeth and as a cofactor in enzymes to perform crucial functions across various biochemical and physiological processes from cell membrane stability, neurotransmission, and synthesis of fats, proteins, and nucleic acids [28]. Magnesium is also an essential nutrient constituting bones alongside calcium indicating that it is highly important during the growth of children

in relation to skeletal health. The inadequate intake of such a variety of nutrients could cause poor growth and reduced muscle strength so that the affected individuals spend most of their time in bed. The reduced immunity could also induce various other diseases. Thus, adequate nutrient supply is indispensable for a healthy life.

Among the 90 participants in this study, 46 completed the 12-week supplementation with a compliance of greater than 80%, and their levels of nutrient intake except for the intake of magnesium showed a significant increase with a consequent effect on weight gain. The changes in physical characteristics in accordance with the compliance to the supplementation showed a significant increase in height, weight, and BMI after the intake of protein nutrient drink across all 90 participants. In addition, 35 participants even with 50% to < 80% compliance also showed a significant increase in height, weight, and BMI (data not shown) suggesting that continuous supply of nutrients could improve the nutrient status in children with brain lesions.

In line with this, numerous studies have been conducted in overseas countries investigating the nutrient status and physical characteristics per disability (cerebral palsy, developmental disorder) in accordance with established guidelines of dietary management [21]. In South Korea, however, the children and adolescents with disabilities as well as those with brain lesions are yet to be assessed for nutrient status, while there is no guideline for nutrient intake. Thus, it is necessary that a guideline of nutrient supply and health management be developed based on the findings in studies investigating the nutrient status and physical characteristics of children and adolescents with disabilities in South Korea.

There were several limitations in this study. First, only approximately half ($n = 46$) of the participants in this study showed 80% or higher compliance to the intake of protein nutrient drink as children with brain lesions often face difficulties in drinking or could not finish the amount provided. Second, the InBody device was used to measure the muscle mass to estimate muscle health, but, because of the involuntary movements or rigidity of a body part in certain children with brain lesions, accurate measurements were difficult to obtain. Third, we are aware of the failure to use a control group (same population with no supplementation) can make it impossible to draw meaningful conclusion, but we did not want to expose them to the potential harms of non-treatment.

Nevertheless, we suggest that reinforced education and management of compliance to supplementation should be ensured for the participants in order to receive an adequate nutrient supply. Furthermore, patient-centered tools of assessing nutrient status and body composition for children and adolescents with disabilities should be developed to ensure better patient care.

CONCLUSION

Through a survey of dietary intake and physical measurements for children with brain lesions in this study, the levels of growth and nutrient intake were found to be significantly lower in these children than in healthy children. In addition, compared to children aged 8–11 years, those aged 12–19 years showed lower levels of proteins, leucine, and vitamin D as part of nutrient intake assessment, while the requirement of these nutrients that promote muscle growth was higher in children aged 12–19 years as they undergo adolescence with distinctly increased

skeletal growth [29]. Therefore, the level of calorie intake as well as nutrient intake for proteins, calcium, and vitamin D required for muscle and skeletal growth in children and adolescents should be increased. The effects of a 12-week intake of protein nutrient drink with respect to the level of nutrient intake, nutrient status, and muscle status before and after the intake yielded significant improvements in nutrient status as well as physical and muscle health.

While we successfully showed that the supplementation of nutrients through beverages is predicted to help improve the nutrient status and health of children and adolescents with brain lesions, further studies regarding the development of specific guidelines on nutrient intake for this population should be urgently conducted. The findings in this study are expected to serve as basic data in the development of guidelines of nutrient intake for children with severe disabilities in South Korea.

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