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A 24-week intervention based on nutrition care process improves diet quality, body mass index, and motivation in children and adolescents with obesity

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ABSTRACT

Higher motivation could support to lead behavioral change for obese children and adolescents. This study aimed to evaluate the effects of a nutrition care process (NCP)–based intervention targeted on diet and weight status in moderate to severe obese children and adolescents in Korea. One hundred four subjects (mean age: 10.95 years, body mass index (BMI) ≥97th percentile of age-sex) participated in the present study. Subjects were divided into a usual care group (UG) and a nutrition group (NG). All participants underwent nutrition education 6 times. The NG received individual access and continuous monitoring and setting goals with respect to nutritional problems. Consumption of high-calorie, low-nutrient (HCLN) food was significantly decreased ($P < .05$) and the Diet Quality Index-International (DQI-I) score also increased with respect to sodium ($P < .001$). The total self-efficacy score was increased from 9.15 to 10.14 points ($P < .01$). After 24 weeks, the BMI-z-score decreased from 2.27 to 2.19 in the NG ($P < .05$); however, no group difference was found. BMI-z-score was negatively associated with self-efficacy ($\beta = -0.03$, $P < .019$). NCP-based intervention might be helpful to solve dietary problems by enhancing self-efficacy and lower BMI-z-score in moderately to severely obese children and adolescents.

Abbreviations: **AC**, Action; **BMI**, body mass index; **CON**, contemplation; **DBP**, diastolic blood pressure; **DQI-I**, Diet Quality Index–International; **HC**, hip circumference; **HCLN**, high calorie and low nutrition; **IDNT**, International Dietetics and Nutrition Terminology; **INQ**, Index of Nutritional Quality; **KDRIs**, Dietary Reference Intakes for Korean; **MFDS**, Ministry of Food and Drug Safety; **MT**, maintenance; **MUFA**, monounsaturated fatty acid; **NCP**, nutrition care process; **NG**, nutrition group; **PP**, preparation; **PRE**, pre-contemplation; **PUFA**, polyunsaturated fatty acid; **SBP**, systolic blood pressure; **SFA**, saturated fatty acid; **SOC**, stage of change; **UG**, usual care group; **UL**, upper level of intake; **WC**, waist circumference.

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1. Introduction

A worrisome global trend has emerged regarding severely obese children and adolescents [1] . In the United States, it is estimated that about 5% of the child population are severely obese [2] The prevalence of severe obesity among children and adolescents in Korea increased steadily from 0.8% to 2% from 2008 to 2017 [3].

Obesity is caused by interactions between the environment, genetic factors, and diet-related individual behaviors [4]. Diet is the main modifiable key factor related to obesity and can reduce the risk of metabolic disabilities such as diabetes mellitus, cardiovascular disease, and nonalcoholic fatty liver [5]. Severely obese children and adolescents with high BMI have not only higher risk of morbidity but also stronger association of dietary problems involving energy dense, high-saturated-fat [6], higher fast food consumption, and eating-out [7].

Nutrition care process (NCP) is a systematic approach designed to meet the dietary needs of individual patients [8]. Previously, we demonstrated the effectiveness of customized nutritional intervention by adapting the NCP model in Korean children and adolescents with moderate to severe obesity [9]. A fabulous improvement in body composition including BMI-z score, as well as macronutrient intake, was presented in highly motivated children and adolescents. Furthermore, the stage of change was higher in both groups after 16 weeks of intervention.

Motivation could have a major role in behavioral therapy to change dietary behavior for obese children and adolescents [10]. Motivation and self-efficacy lead to higher performance and attainable goal setting [11]. Self-efficacy and SOC reflect an individual's motivation to change their behavior in the future [12,13]. In previous studies, increased self-efficacy resulted in a median weight loss in obese children [10], and increased SOC has been associated with decreased fat intake and increased vegetable and fruit intake [14-16].

There have been many multidisciplinary intervention studies including nutritional elements for overweight and obese children [17], but there is a lack of intervention studies focused on dietary problems for moderately to severely obese children and adolescents who can be more susceptible to dietary problems and diseases than obese and overweight children and adolescents [1]. We hypothesized that an NCP-based individual nutritional intervention program could improve diet quality and BMI-z score in moderately to severely obese children and adolescents. Therefore, the aim of this study was to identify the effects of a 24-week nutritional intervention using NCP for moderately to severely obese children and adolescents.

2. Methods and materials

2.1. Study design and participants

This study was a quasi-experimental trial designed to implement a lifestyle intervention in children and adolescents with moderate to severe obesity (Clinical Research Information Service, CRIS.nih.go.kr identifier KCT0002718). Recruitment was achieved through online media (blog, social network service, TV, newspapers) and office of education and schools from November 2016 to February 2018 near Seoul and Gyeonggi province, South Korea. Children and adolescents with a mental illness and those with learning disabilities were excluded from participation. Written informed consent was obtained from all subjects and their caregivers.

A consecutive randomization procedure was used by the unblinded senior researcher to allocate participants into groups. Eligible one hundred sixty-eight participants aged 6 to 17 years with a body mass index (BMI) $\geq 97^{th}$ percentile of age-sex specifics were enrolled at baseline. The flow diagram in Fig. 1 describes subject allocation and intervention (Fig. 1). This study was conducted for 24 weeks, and subjects were randomly assigned in a 1:1 ratio to usual care (UG) and nutrition (NG) groups. The UG and NG received basic nutrition education, and the NG received an additional individual nutritional intervention for 24 weeks. Physical activity was encouraged and assigned by the senior research director through videos and handouts to all of the subjects during the 24-week intervention period. A total of 104 subjects (attrition rate = 38%) completed the 24 weeks of intervention and were included in the analyses.

2.2. Anthropometrics measurements

Body weight and body composition were measured by Bioelectrical Impedance Analysis (InBody 720 Body Composition Analyzer, Bio Space Co., Ltd., Seoul, South Korea). Height was measured by a stadiometer (DS-103, DongSahn Jenix, Seoul, South Korea), with the participant barefoot. Subjects were dressed lightly without shoes before weight and height measurement. The mean value was used for analysis. The 2007 Korean Children and Adolescents Growth Standard [18] was used for anthropometric assessment and BMI reference data specific for age and sex of the subject. BMI percentile was calculated as weight in kilograms divided by height in meters squared. BMI z-scores were calculated and adjusted for age and sex using the lambda-musigma (LMS) method and Korean national growth charts. Body mass index (BMI) was calculated using the formula weight (kg)/height $(m)^2$.

2.3. Nutrition education (both UG and NG)

Table 1 shows nutrition education topics provided for all subjects regardless of group during the 24 weeks. We utilized formerly developed contents of nutrition education that aimed to promote healthy dietary habits by reducing unhealthy eating behaviors of moderate to severely obese children and adolescents [19]. Biweekly (for visit 1 to visit 3) and monthly (visit 4 to visit 6) nutrition education was provided for individualized nutritional advice and treatment for the participants. All nutrition education was performed 6 times (visit 1 to visit 6) by a nutritional expert. At baseline, children's problematic meal patterns were assessed based on dietary behavior survey and food records.

For visit 1 to visit 3, participants learned about healthy eating and balanced diet using "Five food groups" of *grain, protein, vegetable, fruit, diary* groups; "Eating healthy proteins"

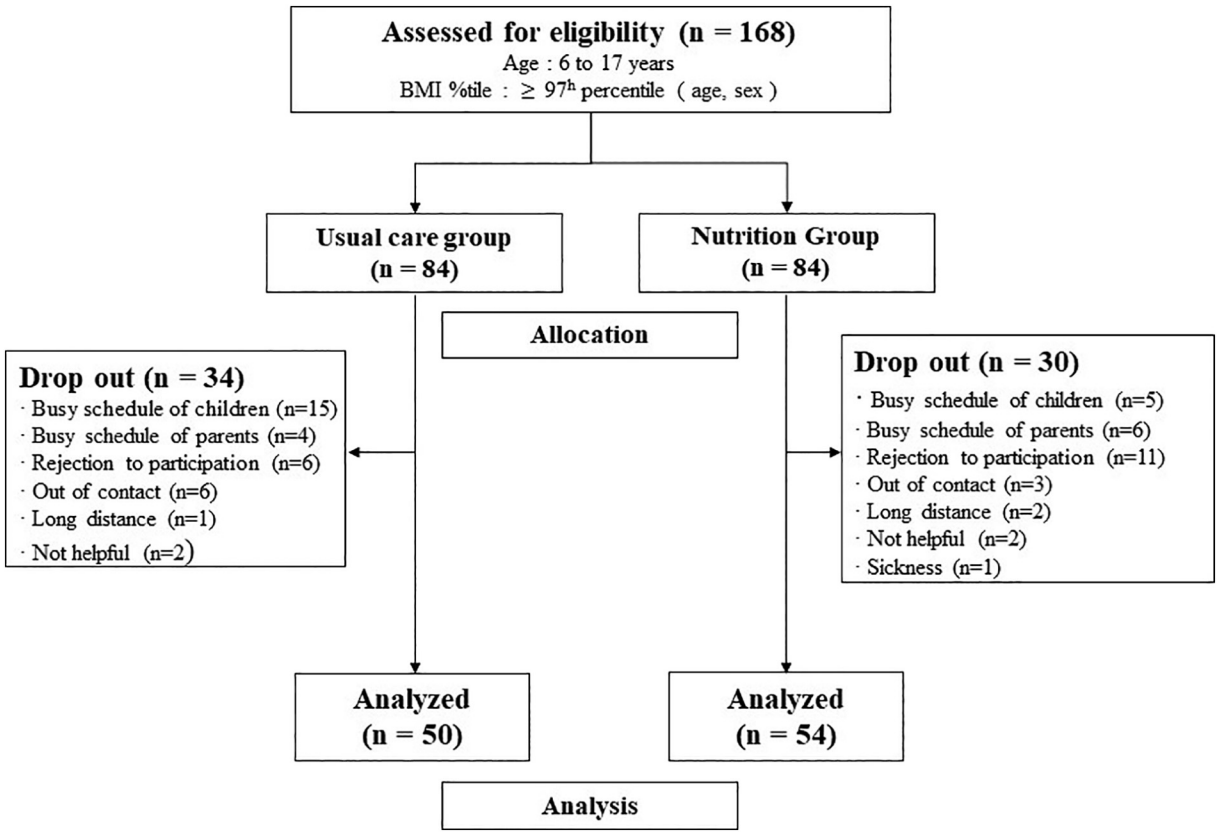

Fig. 1 – Flow diagram of the progression of subjects

(*healthy vs unhealthy proteins*); and "Five colors of vegetable/fruit" (*Bioactive phytochemicals and functional properties of vegetable and fruit*). Monthly sessions for visit 4 to visit 6 to support change in the participants' real life and eating behaviors based on items such as "Measuring one serving using hands" (*amounts of rice, meat, vegetables, fruits, and sauce using hands*), "Nutrition label," and "High calorie-low nutrition (HCLN) food" were taught by a nutritional expert.

2.4. *Individualized NCP (NG only)*

An individualized NCP is shown in Table 1. In this study, NCP was applied only to the NG in the four steps of nutrition assessment, nutrition diagnosis, nutrition intervention, and nutrition monitoring/ evaluation [19,20]. For nutrition assessment and diagnosis, dietary problems (nutritional intake, behavioral and clinical factors) were noted based on the 3-day food record and an interview by the nutritional expert. After diagnosing nutritional problems, the nutrition expert let children and adolescents in setting goals to solve their dietary problems. Nutrition monitoring was performed to identify the nutritional problems and goals of the NG established during the previous visit. During the 24-week intervention, 6 sessions with the NCP were implemented at one-to-one nutritional counseling.

2.5. *Dietary assessment*

Dietary intake was assessed using the 3-day food record (2 weekdays and 1 weekend). Food and nutrients intakes of the subjects were analyzed by CAN-pro (Computer Aided Nutritional Analysis Program, Web version 5.0, Korean Nutrition Society, 2016). The criteria for high-calorie, low-nutrition (HCLN) food are in accordance with those of the Ministry of Food and Drug Safety in Korea [21]. These nutritional standards identify HCLN food that may lead to obesity or malnutrition in children and adolescents. HCLN food is divided into two types, snacks (*cookies, bread, chocolate, ice cream, processed sausage, soda*) and meal substitutes (*ramen, instant kim-bab, hamburger, sandwich*). Diet Quality Index-International (DQI-I) [22] was used to assess dietary quality. This study modified the DQI-I according to the guidelines provided by the Korean Nutrition Society 2015 diet instructions for children and adolescents [23]. The DQI-I consists of four subcategories of variety, adequacy, moderation, and overall balance. Total scores ranged from 0 to 100, with a higher score representing better dietary quality.

2.6. *Motivation*

Self-efficacy and SOC of the participants were evaluated at baseline and 24 weeks. We developed subcategories of motivation, understanding, and prediction of change to assess self-efficacy of the participants. Each subcategory item was scored on a 5-point Likert scale from 1 to 5, with a total possible score of 15 points. Higher score indicates higher self-efficacy.

According to the behavioral change steps of the transtheoretical model [24] , SOC (pre-contemplation, contemplation, preparation, action, and maintenance) was used to identify participant motivation to solve dietary problems.

Table 1 – Nutrition education topics for two intervention groups and individualized NCP

Visit	Nutrition education (both UG and NG) [a]	Individualized NCP (NG only)[b]
Baseline (week 0)	- Dietary assessment: 3-day food records, food-related questionnaires - Motivation: stage of change, self-efficacy, dietary behavior	
Visit 1 (week 4)	**Topic 1. Five food groups** - Simple quiz: *Which diet is more balance?* * Material: food diary, shopping basket	- A/ D: Identify nutrition intake, behavior problems - I: Goal setting, elevating self-efficacy - Take home message: *Take a picture of five food groups at home*
Visit 2 (week 6)	**Topic 2. Eating healthy proteins** - Simple quiz: *Which foods are more healthy proteins?*	- A/ D: Identify nutrition intake, behavior problems - I: Goal setting, elevating self-efficacy - M/E: Intervention monitoring and evaluation - Take home message: *Food record- type of proteins what you eat*
Visit 3 (week 8)	**Topic 3. Five colored vegetables and fruits** - *Consist of red, yellow, green, white, black color*	- A/ D: Identify nutrition intake, behavior problems - I: Goal setting, elevating self-efficacy - M/E: Intervention monitoring and evaluation - Take home message: *Food record- color of vegetable and fruits what you eat*
Visit 4 (week 12)	**Topic 4. Food portion control** - Amount of rice, meat, vegetables, fruits and sauce using hands and fingers * Material: food mat for portion control	- A/ D: Identify nutrition intake, behavior problems - I: Goal setting, elevating self-efficacy - M/E: Intervention monitoring and evaluation - Take home message: *Food portion control*
Visit 5 (week 16)	**Topic 5. Nutrition facts label** - Check sugars, fat (saturated fat, trans fat), sodium - Simple quiz : *comparing healthy food*	- A/ D: Identify nutrition intake, behavior problems - I: Goal setting, elevating self-efficacy - M/E: Intervention monitoring and evaluation - Take home message: *Read nutrition fact label at supermarket*
Visit 6 (week 20)	**Topic 6. High-calorie low-nutrition food** - Simple quiz : *choosing nutritious food*	- A/ D: Identify nutrition intake, behavior problems - I: Goal setting, elevating self-efficacy - M/E: Intervention monitoring and evaluation - Take home message: *Check nutrition fact label of total energy, saturated fat, sugar, protein contents*
24 weeks	- Dietary assessment: 3-day food record, food-related questionnaires - Motivation: stage of change, self-efficacy, dietary behavior questionnaires	

Abbreviation: NCP, Nutrition care process; UG, usual care group; NG, nutritional care group.

[a] Nutrition education was implemented to target both groups individually for 24-week. [b.] Individualized NCP was performed to NG only by a nutritional expert at six times of visits (visit 2-visit 7). NCP was implemented using the following four steps: 1. nutrition assessment (A), 2. nutrition diagnosis (D), 3. nutrition intervention (I), and 4. monitoring/evaluation (M/E) (Academy of Nutrition and Dietetics; 2003).

2.7. Outcomes

The primary outcomes of the present study were changes of DQI-I and HCLN food consumption. Secondary outcomes were changes in BMI-z-score, intakes of macronutrients, (energy, carbohydrate, fat, protein), and motivation (self-efficacy and SOC).

2.8. Statistical analyses

All data were analyzed using the Statistical Package for Social Science (SPSS) ver. 23 (SPSS Inc, Chicago, IL, USA). Statistical significance was defined as $P < .05$. Significant differences in DQI-I score, BMI-z-score and self-efficacy, and SOC of the 2 intervention groups were identified using Student *t* test. The paired *t* test was used to compare the baseline and 24-week intervention outcomes in the groups. Categorical variables were analyzed using χ^2 test. The group-by-time interaction analysis for repeated measures in the generalized estimating equation for categorical variables and mixed effects linear regression models for continuous variables indicated between-group differences in anthropometrics, data, and dietary intake over time. As potential confounders, we considered age, sex, household income (low, low to middle, middle and high), physical activity (METs) and energy intake were adjusted in the mixed effects linear regression models. The intercept was used for linear mixed model random effects at the individual level. To analyze the association between self-efficacy, SOC, and BMI-z-score, multiple regression analysis was conducted with adjustment for confounding variables (age, sex, physical activity, household income, and energy intake). All data were recorded as mean ± SD for continuous variables or n (%) for categorical variables.

3. Results

3.1. General characteristics of the participants

At baseline, 168 children and adolescents assessed as eligible according to the inclusion criteria [53% moderately obese (97th percentile ≤ BMI < 120% of the 95th percentile) and 27% severely obese (BMI ≤ 120% of the 95th percentile)] were recruited. After the 24-week intervention, a total of 104 youths [mean age: 10.95± 2.08 years, boys: n = 67 (64.4%)] were analyzed in the present study. There were no significant group differences in sociodemographic characteristics (school grade and age of the participants, metabolic syndrome-related medical history of the parents, and household income) except for parents' education years (data not shown). Regarding *Adequacy*, *Moderation* and *Overall balance* of diet quality and intake of HCLN food, there were no significant group differences between the 2 groups.

3.2. Changes in primary outcomes: dietary quality and HCLN food

After the 24-week intervention, intake of HCLN food including ice cream, bread, and instant noodles was lower in the NG according to paired *t* test (Table 2). However, only instant noodle intake was significantly lower in the NG (from 48.16 ± 76.96 g to 18.96 ± 30.52 g) after adjustment for confounding variables (age, sex, household income, physical activity and energy intake) in mixed effects linear regression ($P = .012$). There were significant differences in the DQI-I results of total score ($P = .002$), variety ($P = .002$), overall food group variety ($P = .001$) vegetable intake ($P = .004$), and fruit intake ($P = .014$) between the two intervention groups at 24-week follow-up (Table 3).

Table 2 – Changes in the intake of high-calorie, low-nutrient food(HCLN)[1] of the participants after 24-week nutritional intervention

	Usual care group (n = 50)			Nutrition group (n = 54)			P[§]
	Baseline	24-week	Δ 24w-0w[2]	Baseline	24-week	Δ 24w-0w	
Cookie (g)	8.23 ±17.20[3]	8.22 ± 19.04	-0.01	8.57 ± 16.90	8.36 ± 14.99	-0.21	.839
Ice cream (g)	21.71 ± 38.63	10.51 ± 22.98[*]	-11.21	29.15 ± 54.87	11.48 ± 26.03[*]	-17.67	.650
Bread (g)	23.04 ± 29.94	21.41 ± 31.33	-1.62	36.78 ± 54.76	19.61 ± 27.06[*]	-17.17	.154
Instant noodle (g)	29.75 ± 57.74	28.51 ± 54.17	-1.25	48.16 ± 76.96	18.96 ± 30.52[**]	-29.20	**.012**
Pizza (g)	11.14 ± 30.14	8.46 ± 28.93	-2.68	17.86 ± 42.13	13.53 ± 39.67	-4.33	.564
Soda (ml)	42.43 ± 71.80	25.64 ± 50.91	-16.79	29.95 ± 60.87	14.40 ± 33.54	-15.55	.958
Soft drink (ml)	37.30 ± 85.65	16.21 ± 56.06	-21.09	36.47 ± 66.28	29.62 ± 66.37	-6.85	.375
Hamburger (g)	2.33 ± 8.31	6.50 ± 19.06	4.17	4.56 ± 16.21	4.15 ± 16.93	-0.41	.609
Chocolate (g)	0.44 ± 2.01	0.67 ± 3.10	0.23	1.76 ± 12.71	0.19 ± 0.98[†]	-1.57	.330

[1] High-calorie, low-nutrient (HCLN) foods, as defined by the Ministry of Food and Drug Safety, may cause obesity or nutritional imbalance. These foods are divided into two types: snacks and meals. Snacks are defined as intake of calories exceeding 250 kcal, sugar exceeding 17 g, saturated fat exceeding 4 g, or protein less than 2 g.
If protein is above 2 g, we could define HCLN food as a snack when the calorie exceeds 500 kcal, sugar exceeds 34 g, or saturated fat exceeds 8 g. HCLN food meals are defined as intake of calories exceeding 500 kcal, saturated fat exceeding 4 g, protein less than 9 g, or sodium exceeding 600 mg.
But if not, calories exceeding 1000 kcal or saturated fat exceeding 8 g could define HCLN food as a meal.
[2] Subtracting the baseline from the 24-week value.
[3] Values are means ± SD.
[*] Significant difference at *P < .05, **P < .01 by paired *t* test.
[†] Significant difference between the groups by Student *t* test at P < .05.
[§] Group × time interaction effects adjusted for age, sex, household income, physical activity and energy intake in the mixed effects linear regression models.

Table 3 – Changes in the DQI-I after 24-week nutritional intervention of the participants after 24-week nutritional intervention

	Usual care group (n = 50)			Nutrition group (n = 54)			$P^{\S}$
	Baseline	24-week	Δ 24w-0w [1] [2]	Baseline	24-week	Δ 24w-0w	
Total score (0-100)	56.37 ± 7.15[2†]	51.44 ± 7.79***	-4.93	53.62 ± 7.48	54.22 ± 8.20	0.60	**.002**
Variety (20)	11.24 ± 3.37†	9.49 ± 2.89**	-1.75	9.96 ± 2.53	10.44 ± 2.62†	0.48	**.002**
Overall food group variety (15)	7.12 ± 2.59†	5.71 ± 2.02**	-1.41	5.98 ± 1.79	6.52 ± 1.82†	0.54	**.001**
Within-group variety for protein source (5)	4.14 ± 0.95	3.70 ± 1.02*	-0.44	3.97 ± 0.99	3.96 ± 1.00	-0.10	.056
Adequacy (40)	26.35 ± 4.47	22.37 ± 5.83***	-3.97	25.38 ± 4.98	23.11 ± 5.49***	-2.27	.111
Vegetable group (5)	2.07 ± 0.89	1.29 ± 0.71***	-0.78	1.85 ± 0.76	1.69 ± 0.79†	-0.16	**.004**
Fruits group (5)	1.89 ± 1.46†	1.22 ± 1.54*	-0.67	1.34 ± 1.45	1.51 ± 1.64†	0.17	**.014**
Grain group (5)	3.65 ± 1.06	3.16 ± 1.03**	-0.49	3.82 ± 0.94	3.31 ± 0.99**	-0.51	.672
Fiber (5)	3.56 ± 0.89	2.99 ± 1.09***	-0.57	3.58 ± 0.93	3.03 ± 1.07**	-0.55	.782
Protein (5)	4.83 ± 0.47	4.60 ± 0.71*	-0.23	4.89 ± 0.35	4.49 ± 0.88***	-0.40	.265
Iron (5)	4.51 ± 0.83†	3.84 ± 1.02***	-0.67	4.27 ± 0.94	4.00 ± 0.99*	-0.27	.083
Calcium (5)	2.73 ± 1.16	2.30 ± 1.14*	-0.44	2.67 ± 1.11	2.41 ± 0.99	-0.26	.439
Vitamin C	3.07 ± 1.21	2.76 ± 1.16	-0.31	2.93 ± 1.08	2.67 ± 1.14	-0.26	.976
Moderation (30)	16.61 ± 4.12	17.32 ± 4.86	0.71	16.07 ± 4.35	17.97 ± 5.26*	1.90	.360
Total fat (6)	2.04 ± 1.37	2.10 ± 1.48	0.06	2.08 ± 1.36	2.55 ± 1.46	0.47	.497
Saturated fat (6)	5.17 ± 1.27	4.90 ± 1.37	-0.27	5.40 ± 1.19	5.09 ± 1.61	-0.31	.887
Cholesterol (6)	5.05 ± 1.50	4.19 ± 1.89*	-0.86	4.91 ± 1.75	4.59 ± 1.35	-0.32	.185
Sodium (6)	2.17 ± 1.60	3.41 ± 1.81***	1.24	1.65 ± 1.71	3.19 ± 1.82***	1.54	.427
High calorie-Low nutrition food (6) [3]	2.14 ± 1.61	2.70 ± 2.08	0.56	2.00 ± 1.91	2.60 ± 1.98	0.60	.894
Overall balance (10)	2.17 ± 1.64	2.26 ± 1.77	0.09	2.21 ± 1.67	2.70 ± 1.78	0.49	.554
Macronutrient ratio (6) [4]	1.55 ± 1.37	1.45 ± 1.30	-0.10	1.39 ± 1.35	1.91 ± 1.45	0.52	.253
Fatty acid ratio (PUFA:MUFA:SFA)	0.67 ± 0.89	0.69 ± 0.69	0.02	0.78 ± 0.97	0.75 ± 1.20	-0.03	.488

DQI-I, Diet quality index-international; MUFA, monounsaturated fatty acid; SFA, saturated fatty acid; PUFA, polyunsaturated fatty acid.
[1] Subtracting the baseline from the 24-week measurement.
[2] Values are means ± SD.
[3] High-calorie, low-nutrition foods, as defined by the Ministry of Food and Drug Safety, may cause obesity or nutritional imbalance.
[4] Ratio of energy from carbohydrate to protein to fat.
* Significant difference within the groups by paired t test at *P <.05, **P <.01, ***P <.001.
† Significant difference between the groups by Student's t test at P <.05.
§ Group × time interaction effects adjusted for age, sex, household income, physical activity and energy intake in the mixed effects linear regression models at *P <.05.

3.3. *Changes in secondary outcomes: **anthropometrics, dietary intake, and motivation***

Table 4 shows changes in secondary outcomes. For anthropometric data, all subjects were higher in height and lower in weight and body fat mass (%) after 24 weeks of nutritional intervention according to paired t test. BMI-z-score decreased in only the NG, from 2.27 ± 0.48 to 2.19 ± 0.05 ($P < 0.01$). With regard to dietary intake, all subjects showed a decrease in energy kcal (usual care group: 2183.27 ± 628.65 kcal vs 1754.39 ± 86.14 kcal, $P < .001$; nutrition group: 2246.41 ± 459.30 kcal vs 1795.44 ± 486.53 kcal, $P < .001$), carbohydrates (usual care group: 294.27 ± 89.69 g vs 239.38 ± 84.44 g, $P < .001$; nutrition group: 305.74 ± 66.42 g vs 249.55 ± 71.93 g, $P < .001$), fat (usual care group: 72.02 ± 26.13 g vs 58.86 ± 23.33 g, $P < .01$; nutrition group: 74.24 ± 24.68 g vs 57.13 ± 19.58 g, $P < .001$), and sodium (usual care group: 3722.45 ± 1397.95 mg vs 2928.54 ± 958.12 mg, $P < .001$) intakes. However, no group differences in dietary intake were found between NG and UG.

Changes in motivation resulted in increased of the total score of self-efficacy in only the NG from 9.15 ± 2.39 to 10.14 ± 1.85 ($P < .01$) after 24 weeks. After nutritional intervention, 30.2% of the NG was in the maintenance stage ($P < .001$) compared with 16.0% of the UG ($P < .001$).

3.4. *Association between BMI-z-score and motivation*

The associations between BMI-z-score and motivation (self-efficacy and SOC are shown in Table 5. Self-efficacy was negatively associated with BMI-z-score ($\beta = -0.03$, $P = .016$). The association remained after adjustment for age, sex, household income, physical activity and energy intake ($\beta = -0.03$, $P = .019$).

4. Discussion

Individual nutritional intervention based on the NCP for moderately to severely obese children and adolescents was implemented for 24 weeks. We found that primary outcomes (HCLN food, DQI-I) and secondary outcomes (motivation, BMI-z-score) improved after 24 weeks of the nutritional intervention. It was also confirmed that high self-efficacy was associated with low BMI-z-score.

Consumption of HCLN food with a large amount of sodium [25] is associated with dietary risk and poor dietary quality [42] in children and adolescents. In the present study, overall dietary quality including a variety of food groups with small HCLN food intake and a sodium score of DQI-I were improved after 24-week individual nutritional intervention in the NG.

Table 4 – Changes in anthropometric, dietary intake and motivation of the participants after 24-week nutritional intervention

	Usual care group (n = 50)			Nutrition group (n = 54)			
	Baseline	24-week	Δ 24w- 0w [1]	Baseline	24 weeks	Δ 24w-0w	P [§]
Anthropometric							
Height (cm)	151.89 ± 13.50[2]	154.92 ± 13.10***	3.03	153.28 ± 11.97	156.16 ± 11.67***	2.88	.565
Weight (kg)	66.66 ± 19.31	70.09 ± 19.17***	3.43	68.36 ± 18.96	70.87 ± 19.17***	2.51	.187
BMI-z-score	2.27 ± 0.51	2.25 ± 0.55	-0.02	2.27 ± 0.48	2.19 ± 0.55**	-0.07	.123
Body fat mass (kg)	26.62 ± 9.11	27.26 ± 8.66	0.64	27.55 ± 9.86	27.51 ± 10.25	-0.04	.232
Body fat mass (%)	39.68 ± 4.71	38.76 ± 5.04**	-0.91	39.90 ± 5.85	38.43 ± 6.43*	-1.47	.288
Dietary intake							
Energy (kcal)	2183.27 ± 628.65	1754.39 ± 86.14***	-428.88	2246.41 ± 459.30	1795.44 ± 486.53***	-450.97	.893
Carbohydrate (g)	294.27 ± 89.69	239.38 ± 84.44***	-54.89	305.74 ± 66.42	249.55 ± 71.93***	-56.20	.972
Fat (g)	72.02 ± 26.13	58.86 ± 23.33**	-13.15	74.24 ± 24.68	57.13 ± 19.58***	-17.11	.519
Protein (g)	86.33 ± 30.05	68.68 ± 22.19***	-17.64	84.15 ± 18.56	69.90 ± 21.08***	-14.25	.549
C: P: F ratio (%)	54 : 16 : 30	54 : 16 : 30		55 : 15 : 30	56 : 16 : 29		
Sodium (mg)	3722.45 ± 1397.95	2928.54 ± 958.12***	-739.91	3840.72 ± 954.42	2920.25 ± 1092.32***	-920.47	.685
SFA (g)	8.88 ± 5.90	9.36 ± 4.81	0.48	10.75 ± 6.39	9.46 ± 5.61	-1.29	.142
MUFA (g)	8.56 ± 6.36	9.46 ± 6.29	0.90	10.10 ± 6.49	8.97 ± 6.10	-1.13	.141
PUFA (g)	5.78 ± 4.80	7.21 ± 5.87	1.43	5.74 ± 4.26	5.66 ± 4.88†	-0.08	.156
Motivation							
Self-efficacy [3]	9.38 ± 2.42	9.70 ± 1.94	0.32	9.15 ± 2.39	10.14 ± 1.85**	0.99	.126
Stage of change (%)							
Pre-contemplation	10.20	6.00	P <.001‡	9.26	5.66	P <.001‡	.377
Contemplation	36.73	26.00		37.04	22.64		
Preparation	38.78	20.00		33.33	16.98		
Action	10.20	32.00		12.96	24.53		
Maintenance	4.08	16.00		7.41	30.19		

Abbreviations: C:P:F, carbohydrate:protein:fat; SFA, saturated fatty acids; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acids.

[1] It means subtracting the baseline from 24-week.

[2] Values are means ± SD.

[c] Total score of self-efficacy (motivation, understanding, and prediction of adaptation were scored 1 to 5 (5-point Likert)) is 15 points. Higher score means the higher status of the self-efficacy status.

* Significant difference within the groups by paired *t* test at *P <.05, **P <.01, ***P <.001.

† Significant difference between the groups by Student *t* test at *P* <.05.

‡ Generalized estimating equations were used for categorical variables at *P* <.001.

§ Group × time interaction effects adjusted for age, sex, household income, physical activity and energy intake in the mixed effects linear regression models for continuous variables at ‡ *P* < .05.

However, even after nutritional intervention, both groups exceeded the recommended intake of sodium. Similar results have been shown in a previous study. After lifestyle intervention, including nutrition education, the intensive care group showed that the percentage of children who exceeded the upper level of intake (UL, %) of sodium decreased from 86.4% to 39.5%, but the sodium intake of many obese children was still above the recommended level. High sodium intake is a dietary problem, originating from the increased palatability of food and increased energy intake with addition of sodium to food, and it has a positive correlation with BMI-z-score [27,28]. Therefore, individualized education about healthy food choices seemed to be more important for individuals who have dietary problems. Lifestyle intervention for obese children and adolescents resulted in improvement in the healthy lifestyle diet-index [26]. In line with this, goal setting was a key solution to dietary problems in moderately to severely obese children and adolescents.

Motivation, knowledge, and commitment are influential methodologies to increase self-efficacy [31]. For dietary treatment in moderately to severely obese children, motivation is important [32]. Persistent feedback on a subject's dietary problems is powerful to increase motivation [31]. During nutritional intervention, the motivation for changing dietary problems was increased in the NG through increased self-efficacy and SOC. Self-efficacy is the foundation of motivation [32], while SOC indicates the motivational level of subjects and can be used to identify the point at which an individual behavioral change occurred [33]. A previous multidisciplinary intervention study reported change in self-efficacy from 51.3 to 58.7 points in obese children [9,34]. The result suggests that continuous individual monitoring by assessment of food records of obese children attributed to increased self-efficiency. Our study presented greater improvements of SOC in the NG, from low stage (contemplation, preparation) to high stage (action, maintenance), compared to that in the UG, which increased from the low stage (pre-contemplation, contemplation) to the middle stage (contemplation, action). Similar to the results, improvements of SOC were seen in highly adherent moderately to severe obese children and adolescents [9]. Consistently, obese children at higher SOC (action, maintenance) are more receptive to advice

Table 5 – Association between self-efficacy, stage of change (SOC) and BMI z-score by intervention groups

Variables	Δ BMI z-score	Usual care group (n = 50)				Nutrition group (n = 54)			
		β (95% CI)	P	*Adjusted* β (95% CI)	P	β (95% CI)	P	*Adjusted* β (95% CI)	P
Δ Self-efficacy [1]		0.00 (-0.016 to 0.021)	0.791	0.01 (-0.014 to 0.025)	0.570	**-0.03 (-0.050 to -0.005)**	**0.016** *	**-0.03 (-0.054 to -0.005)**	**0.019** *
Δ Stage of change [2]		-0.03 (-0.067 to 0.004)	0.077	-0.03 (-0.064 to 0.011)	0.158	-0.04 (-0.076 to 0.002)	0.064	-0.04 (-0.079 to 0.007)	0.101

[1] Self-efficacy consists of motivation, understanding, and compliance prediction.
[2] Stage of change (SOC) consists of pre-contemplation, contemplation, preparation, action, and maintenance.
* Multiple regression analysis at $P < .05$, adjusted for age, sex, household income, physical activity and energy intake.

about changing their dietary problems than those at lower SOC (pre-contemplation, contemplation) [37]. It appears that increasing motivation, continuous goal setting and monitoring resulted in higher self-efficacy and SOC to produce positive impacts on dietary problems of children and adolescents.

BMI-z-score was decreased by about 3% in NG compared to baseline data. Another study has reported that BMI-z-score decreased about 6% after a 12-week intervention [36]. Although the duration was shorter than that of the present study, the reason for a greater reduction in BMI-z-score was that the previous study focused more on physical activity than nutrition for weight reduction rather than dietary problem improvement of obese children.

Motivational improvement in dietary problems might lead to weight loss in obese children and adolescents. It seems that self-efficacy, the motivation to change dietary problems, increased with achievement of specific goals. In the four steps of the NCP, nutritionists help establish specific goals to solve dietary problems for the NG. Specific goals boost efforts to success with respect to dietary problems and self-efficacy [39]. Higher self-efficacy to solve dietary problems such as reduction of unhealthy diet may have affected the reduction in the BMI-z-score of the NG.

Our study had some limitations. After the 24-week intervention, an about 38% drop-out was observed. Regarding attrition rate, there was a potential for selection bias that could have affected the present results. We used a consecutive randomization procedure in assigning participants but did not consider geographic factors or personal circumstances. It is also possible that there were systematic differences between participants and those who were excluded. Nevertheless, there were no significant differences in the main outcomes between the completers and dropped-out groups (data not shown). Secondly, a wide range of participant age was included in the analysis due to low enrollment for the intervention. It is possible that this resulted in selection bias or misclassification in the results, although no age or sex differences were found in the per protocol analysis (data not shown). However, 27% to 73% of dropout rates were reported in other pediatric intervention programs [38]. In previous research, positive changes and association between BMI-z score and quality of diet in children and adolescents were presented with a greater than 37% drop-out rate [40]. In line with this, the current result showed higher DQI-I and a positive association between BMI-z score and self-efficacy in the NG.

Under-reporting is common in dietary-based intervention, especially in overweight or obese individuals [38]. Normally, under-reporting applies to energy (kcal) or macronutrient (g) intake of the subjects. Self-reported food record might not be adequately reflecting actual dietary intakes of the subjects with obesity. Therefore, a nutritional expert tried to obtain additional information (snacks, SSB, and unhealthy eating behaviors) of the subjects during individual nutritional counseling. It is also double-checked to obtain real intakes of their meals by using portion size and food model during the one to one counseling. In previous studies, [26,40] assuming the presence of under-reporting, large changes in behaviors and body composition including BMI-z score were observed in children and adolescents. Consistently, significant group differences were shown for not only behavioral change, but also in dietary factors (overall food group variety, fruits, and vegetable intake) in the present study.

Although there were few limitations, our results support the research hypothesis that 24-week, NCP-based nutritional intervention can improve diet and health in moderately to severely obese children and adolescents. The present results of this study could be applied to nutritional care and weight management for moderately to severely obese children in Korea and other countries and to assist in maintaining a healthy diet for this population.

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Author contributions

H. Lim, Y. Kim, and K.H. Park were the principal investigators of the Intervention for Childhood and Adolescents Obesity via Activity and Nutrition (ICAAN) project. K.H. Park contributed

to the funding acquisition. H.-J. Lee and S.I. Park co-supervised the research. J. Kim, S. Oh and H. Lim designed and conceptualized for the intervention study. S.R. Woo and H.B. Jang curated the original data. S.Y Lee and J. Kim developed the original draft of the manuscript, and all authors approved the final version.

REFERENCES

[1] Kelly AS, Barlow SE, Rao G, Inge TH, Hayman LL, Steinberger J, et al. Severe obesity in children and adolescents: identification, associated health risks, and treatment approaches: a scientific statement from the American Heart Association. Circulation. 2013;128:1689–712.
[2] Skelton JA, Cook SR, Auinger P, Klein JD, Barlow SE. Prevalence and trends of severe obesity among US children and adolescents. Acad Pediatr. 2009;9:322–9.
[3] Ministry of Education. Announcement of sample examination of student health examination for 2016 [Internet]. [cited 2020 Oct 17] Sejong: Ministry of Eduation; 2017 Available from: https://www.moe.go.kr/boardCnts/view.do?boardID=316&lev=0&statusYN=W&s=moe&m=0302&opType=N&boardSeq=73681.
[4] Ogden Cynthia L, Yanovski Susan Z, Carroll Margaret D, Flegal Katherine M. The epidemiology of obesity. Gastroenterology. 2007;132:2087–102.
[5] Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. Nutr Rev. 2012;70:3–21.
[6] Johns DJ, Lindroos A, Jebb SA, Sjöström L, Carlsson LMS, Ambrosini GL. Dietary patterns, cardiometabolic risk factors, and the incidence of cardiovascular disease in severe obesity. Obesity (Silver Spring). 2015;23:1063–70.
[7] Bahadoran Z, Mirmiran P, Azizi F. Fast food pattern and cardiometabolic disorders: a review of current studies. Health Promotion Perspectives. 2015;5:231–40.
[8] Lacey K, Pritchett E. Nutrition care process and model: ADA adopts road map to quality care and outcomes management. J Am Diet Assoc. 2003;103:1061–72.
[9] Kim Jieun, Kim YoonMyung, Seo Young-Gyun, Park Kyung-Hee, Jang Han Byul, Lee Hye-Ja, et al. Evidence-based customized nutritional intervention improves body composition and nutritional factors for highly-adherent children and adolescents with moderate to severe obesity. Nutr Res Pract. 2020;14.
[8] Reinehr T, Brylak K, Alexy U, Kersting M, Andler W. Predictors to success in outpatient training in obese children and adolescents. Int J Obes Relat Metab Disord 2003;27:1087-92.
[10] Reinehr T, Brylak K, Alexy U, Kersting M, Andler W. Predictors to success in outpatient training in obese children and adolescents. Int J Obes Relat Metab Disord. 2003;27:1087–92.
[11] Lunenburg FC. Goal-setting theory of motivation. International Journal of Management, Business, and Administration. 2011;15:1–6.
[12] Bandura A. Self-efficacy: toward a unifying theory of behavioral change. Psychological Review. 1977;84:191–215.
[13] Prochaska J, Diclemente C. Toward a comprehensive model of change. In Treating Addictive Behaviors: Processes of Change. 1986;13.
[14] Jury A, Flett R. Stages of change for fruit and vegetable intake among New Zealand men: readiness to eat five servings a day and impact of contextual factors. International Journal of Men's Health. 2010;9:184–200.
[15] Mason HN, Crabtree V, Caudill P, Topp R. Childhood obesity: a transtheoretical case management approach. J Pediatr Nurs. 2008;23:337–44.
[16] Frenn M, Malin S, Bansal NK. Stage-based interventions for low-fat diet with middle school students. J Pediatr Nurs. 2003;18:36–45.
[17] Mead E, Brown T, Rees K, Azevedo LB, Whittaker V, Jones D, et al. Diet, physical activity and behavioural interventions for the treatment of overweight or obese children from the age of 6 to 11 years. Cochrane Database Syst Rev. 2017;6:CD012651.
[18] Korea Center for Disease Control and Prevention, The Korean Pediatric Society. Korean Children and Adolescents Growth Standard (commentary for the development of 2007 growth chart); 2007.
[19] Kim Jieun, Kim Yoon Myung, Jang Han Byul, Lee Hye-Ja, Park Sang Ick, Park Kyung-Hee, et al. Evidence-based nutritional intervention protocol for Korean moderate-severe obese children and adolescents. Clin Nutr Res. 2019;8:184–95.
[20] Hakel-Smith N, Lewis NM. A standardized nutrition care process and language are essential components of a conceptual model to guide and document nutrition care and patient outcomes. J Am Diet Assoc. 2004;104:1878–84.
[21] Ministry of Food and Drug safety. High Calorie and Low Nutrients food; 2019.
[22] Kim S, Haines PS, Siega-Riz AM, Popkin BM. The Diet Quality Index-International (DQI-I) provides an effective tool for cross-national comparison of diet quality as illustrated by China and the United States. J Nutr. 2003;133:3476–84.
[23] Dietary Reference Intakes for Koreans. Ministry of Health & Welfare; 2015.
[24] Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. American Journal of Health Promotion. 1997;12:38–48.
[25] Maalouf Joyce, Cogswell Mary E, Gunn Janelle P, Curtis Christine J, Rhodes Donna, Kathy Hoy PP, et al. Monitoring the sodium content of restaurant foods: public health challenges and opportunities. Am J Public Health. 2013;103.
[26] Ojeda-Rodríguez A, Zazpe I, Morell-Azanza L, Chueca MJ, Azcona-Sanjulian MC, Marti A. Improved diet quality and nutrient adequacy in children and adolescents with abdominal obesity after a lifestyle intervention. Nutrients. 2018;10.
[27] Yoon YS, Oh SW. Sodium density and obesity; the Korea National Health and Nutrition Examination Survey 2007-2010. Eur J Clin Nutr. 2013;67:141–6.
[28] Bolhuis DP, Lakemond CMM, de Wijk RA, Luning PA, de Graaf C. Effect of salt intensity in soup on ad libitum intake and on subsequent food choice. Appetite. 2012;58:48–55.
[31] Bandura A. Health promotion by social cognitive means. Health Education Behaviour. 2004;3:143–64.
[32] Williams GC, Grow VM, Freedman ZR, Ryan RM, Deci EL. Motivational predictors of weight loss and weight-loss maintenance. J Pers Soc Psychol. 1996;70:115–26.
[33] Burgers C, Eden A, van Engelenburg MD, Buningh S. How feedback boosts motivation and play in a brain-training game. Computers in Human Behavior. 2015;48:94–103.
[34] Bandura A. Perceived self-efficacy in cognitive development and functioning. Educational Psychologist. 1993;28:117–48.
[36] Seo NS, Kim YH, Kang HY. Effects of an obesity control program based on behavior modification and self-efficacy in obese elementary school children. Journal of Korean Academy of Nursing. 2005;35:611–20.
[37] Wee CC, Davis RB, Phillips RS. Stage of readiness to control weight and adopt weight control behaviors in primary care. J Gen Intern Med. 2005;20:410–5.
[38] Shalitin S, Ashkenazi-Hoffnung L, Yackobovitch-Gavan M, Nagelberg N, Karni Y, Hershkovitz E, et al. Effects of a twelve-week randomized intervention of exercise and/or diet on weight loss and weight maintenance, and other metabolic parameters in obese preadolescent children. Horm Res. 2009;72:287–301.
[39] Schunk DH. Goal setting and self-efficacy during self-regulated learning. Educational Psychologist. 1990;25:71–86.

[40] De Miguel-Etayo P, Moreno LA, Santabárbara J, Martín-Matillas M, Azcona-San Julian MC, del Moral AM, et al. López-Belmonte G. Diet quality index as a predictor of treatment efficacy in overweight and obese adolescents: The EVASYON study. Clinical Nutrition. 2019;38:782–90.

[42] Bowman SA, Gortmaker SL, Ebbeling CB, Pereira MA, Ludwig DS. Effects of fast-food consumption on energy intake and diet quality among children in a national household survey. Pediatrics. 2004;113(1):112–8. https://doi.org/10.1542/peds.113.1.112.