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Effect of raw grain cereal diet therapy on obesity factors

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Summary. Obesity is known to cause metabolic disorders such as hyperlipidemia and hypertension, among other diseases, and contribute to mental illnesses such as depressive disorder. The westernization of the Korean diet has led to an increase in the prevalence of obesity in Korea. Diet therapy is considered to have the easiest and quickest effect in obesity treatment of all the modalities; however, it is associated with nutritional imbalances due to calorie restriction. This study aimed to ascertain whether the intake of raw grains as food substitutes can effectively treat obesity. A total of 30 participants underwent diet therapy for obesity treatment, with some meals replaced by raw grains rich in nutrition. In the control group, the body weight decreased to 99.51±2.62% while in the experiment group, it decreased to 95.33±3.74% ($p<0.001$). In the control group, the skeletal muscle weight increased to 98.94±8.39% while in the experiment group, it increased to 87.03±13.02% ($p<0.01$). In terms of fat mass, the value in the control group increased to 103.3±1.23% while that in the experiment group decreased to 95.2±51.37% ($p<0.05$). In terms of extracellular water ratio, the value in the control group decreased to 99.75±3.14% while that in the experiment group decreased to 97.34±4.02% ($p<0.05$). The body mass index (BMI) in the control group decreased to 100.04±5.78% while that in the experiment group decreased to 95.23±8.53% ($p<0.05$). Individual participant research was conducted to complement the weakness of the population sample number; in this, weight and BMI values were found to decrease under conditions of imbalanced nutrition. It was ascertained that participants' dietary habits were corrected through control even when raw grain intake was discontinued.

Keyword: Obesity, Raw Grain Cereal Diet

Introduction

Remarkable developments in medical science have led to an increase in the human life span (1). However, the prevalence rates of incurable illnesses and chronic diseases, such as obesity, have increased (2). While the number of people with acute, life-threatening diseases has decreased to some degree, that of those with chronic diseases has increased rapidly (3).

Among the factors causing chronic diseases are changes in people's food consumption habits (4). There have been significant changes in people's food consumption patterns in the last 30 years, with the introduction of the western food culture, including fast food, and development of the food service industry (5). Owing to an increase in the consumption of foods of animal origin, 22.6% and 23% of all men and women, respectively, had a body mass index (BMI) higher than 25 kg/m^2, suggesting that the number of obese people has increased rapidly (6). Obesity is a potential cause of chronic diseases such as diabetes mellitus and hypertension, and while its prevention may provide a solid foundation for good health, its management can play an important role in chronic disease treatment (7).

To improve the intensity of therapy obesity symptoms, weight loss and the control of the associated side effects is vital (9). Combining diet, behavioral therapy (10) and exercise therapy (11) is effective in improving the symptoms of obesity. Specifically, diet therapy is important for the improvement of obesity-related symptoms (8) in this context, the consumption of raw grains has received attention as a means to reduce calorie intake without minimizing the food intake quantity (10).

Raw grain intake entails the consumption of these grains without first boiling them (11), and can reduce the rates of vitamin, mineral, enzyme and dietary fiber loss due to heat (10). Grains contain several nutrients (11), and their intake can improve dietary patterns and, consequently, people's mental and physical health. Whole grains are grains in which only the inedible parts are removed (12).

This study aimed to measure and ascertain several obesity-related factors with regards to the contribution of raw grains as food substitutes in obesity treatment.

Overweight is not the same as obesity. For some athletes, the presence of increased muscle tissue mass may lead to overweight; this is not referred to as obesity. Cases in which the quantity of fat tissue increases without a corresponding increase in weight, as shown in senior citizens, are referred to as 'non-obese obesity' (13). The surplus accumulation of fat is referred to as obesity, and may lead to hypertension, diabetes mellitus, cardiovascular disease, stroke and depressive disorder (14).

Obesity treatment starts with the measurement of body weight through the calculation of the body mass index (BMI) using the formula:

$BMI = weight (kg) / \{stature (cm)\}^2$

As per the World Health Organization, obesity is defined as a BMI of 30 kg/m^2 or greater. In the Republic of Korea, severe obesity is defined as a BMI of 35 kg/m^2 or greater, moderate obesity (phase 2 obesity) as a BMI of 30 – 35 kg/m^2 and mild obesity (phase 1 obesity) as a BMI of 25 – 30 kg/m^2. Obesity can also be defined based on human body fat using the fatness index, which is highly accessible. Another way to define obesity is to measure the link between body fat percentage and waist circumference. A BMI of 25 kg/m^2 or greater and a waist circumference of 90 cm or greater (in the case of men) is definitive of obesity.

Combining exercise therapy and behavioral therapy can help spread awareness on the link between calories, calorie intake, food and exercise (15).

It may be worthwhile to evaluate whether the intake of cooked food is a necessity in the current obesity scenario. The embryos of raw grains contain high amounts of nutrients that are required for their growth and which are produced by the decomposition of the flesh of seeds. In several fruits, the embryo contains ingredients that decompose the starch of the flesh. Grains contain enzymes required for the growth of the embryo, and destroying them through cooking is unnecessary. The cooking of food leads to the destruction of the aforementioned enzymes, causing surplus carbohydrate accumulation. Surplus contains high dietary fiber levels. Fibers activate ruminal microorganisms and help produce useful enzymes, and also activate enterocinesia, aiding in the proper excretion of waste products from the human body. The physiologically active substances contained in plants extend a high antioxidant effect and aid in balancing the immune system and restricting the production of oxygen free radicals.

Whole grains such as barley (*Hordeum vulgare*) (16), sorghum (*Sorghum bicolor* (L.) Moench.) (17), *Panicum miliaceum* (18), unpolished rice (*Oryza sativa*) (19), black soybean (*Glycine max*) (20), and maize (*Zea mays*) (21) contain high levels of dietary fiber.

Barley, which is consumed in high quantities, worldwide, contains various nutrients including proteins, fats and minerals (22), as well as high levels of β-glucan and water-soluble dietary fiber. Barley effectively improves the symptoms of hypercholesterolemia (23), as β-glucan lowers blood cholesterol levels by impeding the absorption of cholesterol and expediting the excretion of cholesterol (24). In recent times, studies on barley use have been conducted both in Korea and other countries.

Sorghum is an annual plant native to Africa, and grows under highly arid conditions. Grain sorghum, sorgo, and broom-corn are grown according to their use. Sorghum also grows in Asia and Central America (25). The grain contains high levels of active ingredients such as dietary fiber and phenolic compounds (26). A majority of these phenolic compounds are flavonoids (27). The antioxidant ingredients found in sorghum suppress the activation of HMG-CoA reductasean enzyme associated with cholesterol biosynthesis (28). In recent times, some studies focusing on the physiological function of sorghum have been conducted.

P. miliaceum is an annual grass species belonging to the Gramineae family. The cultivation of *P. miliaceum*, which grows in temperate zones with a continental climate such as East Asia and Central Asia, was started by nomads (29). *P. miliaceum* extract is effective in decomposing fat cells as it provides toxicity to 3T3-L1 fat cells (30).

Unpolished rice lowers the levels of blood cholesterol, neutral lipids and low-density lipoprotein cholesterol (LDL-C) and increases those of high-density lipoprotein cholesterol (HDL-C), effectively suppressing the symptoms of obesity (27, 31).

Black soybean, also known as green flesh black bean or choice bean, contains anthocyanin in the seed coat. There are no significant differences between black and yellow soybean in terms of their constituents. The anthocyanin contained in black soybean has strong bioactive functions, such as antioxidation (32). The biological functions of black soybean have received a lot of attention. Various studies (33) have focused on the physiological activation of 'cheonggukjang' (fast-fermented bean paste) produced using black soybean pigment (34) and black soybean, and the effects of the intakes of yellow and black soybean in the antioxidation and anti-aging of white rats (35). The effect of black soybean extract on the serum lipid levels of white rats (36) has also been studied.

Dietary fiber comprises durable and rough ingredients that are not easily decomposed or digested by human digestive enzymes (37). Dietary fiber intake prevents constipation by promoting enterocinesia, and is used by people who are dieting as it lowers the hunger sensation and delays digestion (38).

Maize (*Zea mays*) is among the top three food crops, worldwide, along with rice and wheat, and has various uses (33). Maize contains 7.5% of moisture, 11.5% of protein, 4.6% of lipid, 1.7% of ash, 70.8% of carbohydrate and 3.9% of fiber (39). Maize is effective in preventing the development of obesity, suppressing its symptoms, and treating diseases caused by oxidative stress (40).

Material and methods

Materials

The raw grain meals in this study comprised barley, sorghum, *P. miliaceum*, unpolished rice, black soybean and maize produced by a company located in Chungnam, which were crushed into a mixed-type powder using low temperatures and freezing drying. A total of 50 g of the mixture was put in each bag.

Instrument

InBody770, produced by InBody Co., Ltd. (Seoul, South Korea), was used to measure the levels of body water, protein, mineral, body fat and weight, skeletal muscle mass, body fat percentage and cross-sectional area of visceral fat.

Criteria for participant inclusion and exclusion

Obese people aged 20-60 years who agreed to participate in the experiment were included. For men, the inclusion criteria were a waist circumference of 90 cm or greater and BMI of 25 kg/m^2 or greater. For women, the inclusion criteria were a waist circumference of 85 cm or greater and BMI of 25 kg/m^2 or greater. BMI was calculated as:

BMI = weight (kg) / {stature (m) X stature (m)}

People who were receiving hypertension or diabetes mellitus treatment, who consumed alcohol twice a week or more, who experienced a sharp weight change in the last month, and who were taking drugs affecting the present research were excluded.

Criteria for target participant number identification

A total of 70 people were first recruited. The sample size was identified using G*Power 3.1(41) to ascertain the minimum number of participants required for the experiment. The effect size was f=0.5. A total of four measurements were required. The significance level was set at a=0.05. When the power was set at 90%, the sample number was 30 people. When the elimination rate was set at 20%, the minimum sample number was 36 people. Finally, 50 people were selected as participants in this experiment.

Control group

The reference group comprised people who consumed two or more meals a day.

Randomization

Participants were selected at random by those who did not participate in this study.

Reagent dose: administration method, administration period and reasons for setting the above items

The experiment group consumed 100 g of raw grains a day for four weeks. The intake time was not restricted. Participants were instructed to consume two packs of raw grains a day. Each participant was provided with sufficient raw grains for consumption over two meals per day. During the experiment, participants did not perform any exercise. Participants were advised to consume one pack of raw grains before eating out if they had no choice but to eat out.

All participants were asked to submit a diary record of the experiment a week they wrote before and after conducting an experiment. Participants were interviewed using the 24-hour recall method to check their intake status.

Items observed

Obesity-related factors were analyzed using InBody770 with participants on a footstool; these factors included body composition, weight, BMI, fat mass, body fat percentage, skeletal muscle mass, body water level, protein level, mineral level and body fat level.

Evaluation of compliance

Each participant submitted a diary record of the experiment and was interviewed once a week (Table 1). Through SNS, the meal intake amount and frequency were measured in the control group, and in the experiment group, the raw grain intake amount and frequency were measured. We performed checks on a daily basis to confirm the intake of raw grains. The raw grain intake frequency (number of participants actually consuming raw grains /expected number of participants consuming raw grains X 100) for one week exceeded 90%. In cases in which those in the experiment group failed to consume raw grains and those in the control group had excessive meal intake amounts but an inadequate number of meals, the reasons were discussed through an interview. Each participant was interviewed once a week. Members in the control group were provided with compensation that they took raw grains for two months.

Statistical analysis

All the study findings were analyzed using Window SPSS 23 Program. An independent t-test was conducted to test homogeneity between groups regarding the participants' general characteristics. Repeated analysis of variance was conducted to check for differences between the groups by period. In cases in which significance was observed in the items measured ($^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$), the significance was verified using Bonferroni's correction. Regression analysis was conducted to identify the correlation between raw grain intake and obesity-related factors.

Institutional review board

Study approval was obtained from the Institutional Review Board of Chosun University (2-1041055-AB-N-0102017-00180).

Result and discussion

Participant characteristics

The characteristics of the participants are presented in Table 1. The control and experiment groups comprised 23 people each. The control group comprised six men (26.09%) and 17 women (73.91%), while the experiment group comprised three men (13.04%) and 20

Table 1. General characteristics of the respondents.

		Frequence	%
Control Group	Man	6	26.09
	Women	17	73.91
	Total	23	100.00
Experimental Group	Man	3	13.04
	Women	20	86.96
	Total	23	100.00
Control Group	20s	3	13.04
	30s	1	4.35
	40s	9	39.13
	50s	9	39.13
	60s over	1	4.35
	Total	23	100.00
Experimental Group	20s	5	21.74
	30s	4	17.39
	40s	8	34.78
	50s	6	26.09
	60s over	0	0.00
	Total	23	100.00

women (86.96%). In the control group, three people were in their 20s (13.04%), one person was in his/her 30s (4.35%), nine people were in their 40s (39.13%), nine people were in their 50s (39.13%) and one person was in his/her 60s or higher (4.35%). The experiment group comprised five people in their 20s (21.74%), four in their 30s (17.39%), eight in their 40s (34.78%), and six in their 50s (26.09%). In both the control and experiment groups, the number of women was greater than that of men, suggesting that women are more interested in undergoing obesity treatment. Women are supposed to pursue beauty while men are supposed to treat obesity through raw grain intake. A majority of the participants were in their 40s and 50s, while those in their 20s and 30s accounted for the lowest participation, suggesting that people in their 20s or 30s do not have enough time to dedicate to raw grain intake.

Comparison of obesity-related factors

Obesity-related factors were measured before and after raw grain intake, after some time had elapsed. We evaluated physical constitution changes as a consequence of raw grain intake.

Figures 1 and 2 show the body weight changes before and after raw grain intake. In the control group (Figure 1), when the changes in the obesity-related factors before raw grain intake, after raw grain intake, and during raw grain intake were compared, no statistically significant differences were observed.

In the experiment group, the average weight in the experiment group decreased by 3% during raw grain intake. The weight of the participants in this group decreased by 4% even after they returned to normal life after the completion of raw grain intake. The body weight decrease was ascertained to be statistically significant ($p<0.001$).

The control group showed a slight increase in the skeletal muscle mass, but this was not statistically significant, while the experiment group showed approximately a 3% decrease in the skeletal muscle mass after raw grain intake($p<0.001$).

The control group showed a slight increase in the body fat level, but this was not statistically significant. In the experiment group, the body fat level decreased by 6% during raw grain intake and by 8% after, but these reductions were not statistically significant; this

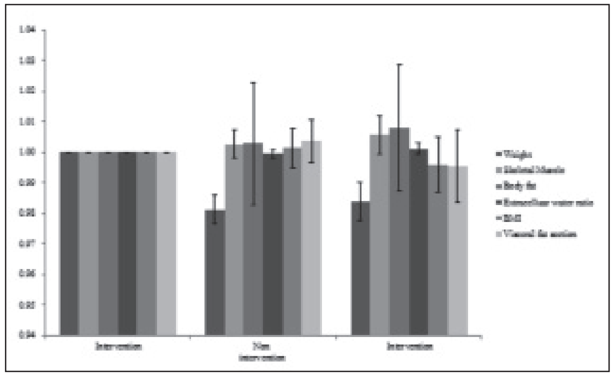

Figure 1. Obesity factors change during the intervention experimental group.

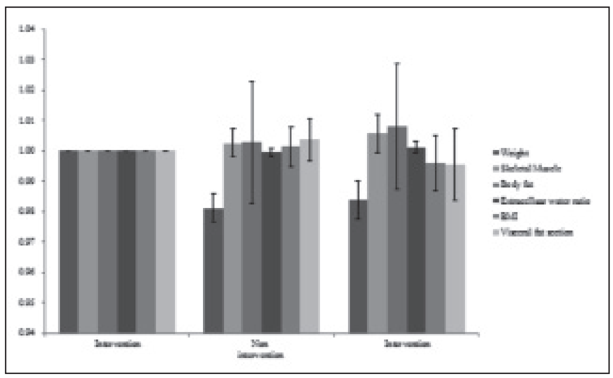

Figure 2. Obesity factors change during the intervention experimental group.

may be attributed to the insufficient participant number.

The control group showed a slight increase in the extracellular water ratio but this was not statistically significant, while the experiment group showed no change in the extracellular water ratio, indicating that there was no loss of water due to raw grain intake.

The control group showed marginal BMI reductions. However, in the experiment group, the BMI decreased by 3% during raw grain intake and by 6% after. The BMI showed a clear decrease ($p<0.001$).

While the control group showed a marginal decrease in the cross-sectional area of visceral fat, the experiment group showed approximately a 3% decrease in the same during raw grain intake and 6% decrease after. As in the case of BMI, the cross-sectional area of visceral fat showed a clear decrease ($p<0.001$). It was ascertained that raw grain intake was effective in treating obesity based on BMI.

In the experiment group, the weight (*p<0.001*), skeletal muscle mass (*p<0.001*) and BMI (*p<0.001*) showed statistically significant decreases. In terms of body fat and the extracellular water ratio, there was no statistically significant decrease.

Comparison of obesity-related factors before and after raw grain intake

The results of the comparisons of the changes in the obesity-related factors before and after raw grain intake are presented in Table 2.

The control group showed a 99.±2.62 decrease in body weight while the experiment group showed a corresponding value of 95.33±3.74. In the control group, the fat mass increased to 103.3±1.23 while in the experiment group, it decreased to 95.24±1.37. In the control group, the extracellular water ratio decreased to 99.72± 3.14% while in the experiment group, it decreased to 97.34±4.02 to up 75± 3. In terms of BMI, the value decreased to 100.04±5.78 to in the control group and 95.23±8.53 in the experiment group. The cross-sectional area of visceral fat did not show a statistically significant decrease.

Correlation between raw grain intake and obesity-related factors

The correlation between raw grain inftake and obesity-related factors is presented in Table 3. This study aimed to identify the correlations among the factors causing weight loss by examining the correlations between the obesity-related factors before and after raw grain intake. Body weight was negatively correlated to raw grain intake. All obesity-related factors except the cross-sectional area of visceral fat showed a significant negative correlation with raw grain intake. The cross-sectional area of visceral fat did not show a significant correlation with raw grain intake and other obesity-related factors. Significant results were observed in terms of the extracellular water ratio on raw grain intake and skeletal muscle. For BMI, raw grain intake and the extracellular water ratio showed only a significant decrease.

The participants' average calorie intakes are presented in Table 4. On comparing the calorie intakes during normal meals, participants with raw grain intake were found to have a very low calorie intake.

In this study, we selected raw grains that could act as food substitutes to provide balanced nutrition. Encouraging participants to keep a diary record helped in promoting life habit improvements. We observed significant body weight reductions after raw grain intake, and confirmed that both the BMI and visceral fat values reduced. Skeletal muscle mass was also found to be reduced. However, the extracellular water ratio did not show a significant decrease, like in the case of skeletal muscle mass. Single-subject research found that the participants' dietary habits had changed, which is expected to have a positive effect in increasing skeletal muscle mass and reducing body fat.

Barley, sorghum, *P. miliaceum*, unpolished rice, black soybean and maize all have a high dietary fiber content, and several studies have reported on their efficacy in obesity treatment. Barley contains an abun-

Table 2. Ratio of obesity factors after intervention

		N	Mean	SD
Weight	Control Group	23	99.51	2.62
	Eperimental Group	23	95.33***	3.74
Skeletal Muscle	Control Group	23	98.94	8.39
	Eperimental Group	23	87.03**	13.02
Body fat	Control Group	23	103.31	18.23
	Eperimental Group	23	95.24*	1.37
Extracelluar water ratio	Control Group	23	99.72	3.14
	Experimental Group	23	97.34*	4.02
BMI	Control Group	23	100.04	5.78
	Experimental Group	23	95.23*	8.53
Visceral fat section	Control Group	23	100.12	1.25
	Experimental Group	23	100.01	2.10

* $p < 0.05$: Means in a column are significantly different at 5% significance level by Duncan's multiple range test.
** $p < 0.01$: Means in a column are significantly different at 0.1% significance level by Duncan's multiple range test.
*** $p < 0.001$: Means in a column are significantly different at 0.01% significance level by Duncan's multiple range test.

Table 3. Correlation between intervention and obesity factors

	Intervention	Weight	Skeletal Muscle	Body fat	Extracelluar water ratio	BMI	Visceral fat section
Intervention	1	-0.552**	-0.486**	-0.304**	-0.319*	-0.320*	-0.033
Weight		1	0.620**	0.384**	0.094	0.358*	0.018
Skeletal Muscle			1	0.392**	-0.453**	0.828	-0.049
Body fat				1	-0.031	0.283	0.005
Extracelluar water ratio					1	-0.704**	0.120
BMI						1	-0.086
Visceral fat section							1

* P<0.05; Correlation is significant at the 0.01 level (2-tailed).
** P<0.01; Correlation is significant at the 0.01 level (2-tailed).

Table 4. Intake energy of intervention and non-intervention period.

	Origin	Intervention	Non intervention	Intervention
Intake energy (kcal)	Food	669.68	1,337.36	935.94
	Raw Grain	388.00	0.00	388.00
	Total	1,057.68	1,337.36	1,323.94
Carbohydrate (kcal)	Food	115.96	220.07	159.65
	Raw Grain	116.00	0.00	116.00
	Total	231.96	220.07	275.65
Fat (kcal)	Food	11.04	19.11	19.36
	Raw Grain	13.50	0.00	13.50
	Total	24.54	19.11	32.86
Protein (kcal)	Food	26.66	40.46	35.35
	Raw Grain	72.00	0.00	72.00
	Total	98.66	40.46	107.35

dance of fatty acid such as linolenic acid and palmitic acid, and is proven to be effective in treating hyperlipidemia and hypercholesterolemia. A study on mice that consumed high-cholesterol foods reported that the obesity-related indices decreased significantly and HDL-C levels increased after barley intake, and also elaborated on its antioxidant effects. In that study, the mice's kidney, liver and heart health were also found to be improved. Mice that consumed the β-glucan contained in barley showed increased HDL-C levels. HDL-C is an indicator in obesity treatment, and conveys the LDL-C in blood to the liver for blood vessel clarification. As the HDL-C level increases, the risk of arteriosclerosis reduces.

Sorghum is rich in phenolic acid and anthocyanin, and contains antioxidant enzymessuperoxide dismutase and glutathione peroxidasethat are effective in treating cancer. Antioxidant enzymes activate the burning of fat and LDL-C decomposition, and also improve lipid metabolism to control the formation and accumulation of human body fat. Superoxide dismutase, a representative antioxidant enzyme, has a strong antioxidant effect, and is helpful in treating obesity. Plants belonging to the genus *Panicum* contain tiny seeds. The species used in this study was *P. miliaceum*, which is rich in γ- tocopherol, α- tocopherol, linolenic acid and oleic acid. A study in which *P. miliaceum* was fed to mice with high fat levels for 12 weeks reported impaired weight gain, and an improved lipid profile and anti-inflammatory status. *P. miliaceum* intake reduces oxidative stress and improves the expression of several obesity-related genes and the proliferation of lactic acid bacteria.

Conclusion

Unpolished rice is rich in phytochemical ingredients such as polyphenol and vitamin, and is expected to replace polished rice in staple diets the world over. Sufficient unpolished rice intake helps lower the risk of obesity, diabetes mellitus and coronary artery disease. Raw grain intake aids in the proliferation of effective microorganisms through the compensation of several dietary fibers contained in wheat bran and an increase in the intake of phytochemicals such as phenolic acid, flavonoid, resistant starch, oligosaccharides, protein, folic acid and tocopherol. The above-mentioned bioactive substances activate lipid metabolism for the treatment of obesity-related complications.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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