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Pragya Verma
Assistant Professor, Keshav Prasad Mishra Government College Aurai, Bhadohi, Uttar Pradesh, India

Ratan K Srivastava
Professor, Department of Community Medicine, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Dr. Dharmendra Jain
Associate Professor, Department of Cardiology, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Corresponding Author:
Pragya Verma
Assistant Professor, Keshav Prasad Mishra Government College Aurai, Bhadohi, Uttar Pradesh, India

Effect of plant-based dietary intervention on visceral fat, anthropometry and body composition in individuals with metabolic syndrome

Pragya Verma, Ratan K Srivastava and Dharmendra Jain

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Abstract

Background: Metabolic syndrome (MetS) is a health problem throughout the world and is associated with cardiovascular disease and diabetes. Given the enduring outbreak of overweight and obesity, it is expected that the prevalence of the metabolic syndrome will continue to grow. Recent evidences suggest that dietary fiber that is rich in whole and unrefined grains is protective and play important role in preventing or delaying the onset of lifestyle diseases.

Objective: This study investigated whether the consumption of a diet in which high-β-glucan barley replaced wheat and rice would reduce the visceral fat area, body weight as well as body composition in patients with metabolic syndrome.

Methods: A total of two hundred four men & women with Metabolic Syndrome aged 30-70 years, participated in a randomized parallel group design comparing a diet rich in soluble fiber β-glucan (Intervention group) with a control diet (Control group)) of similar macronutrient composition but lacking barley. Both diets followed the National Cholesterol Education Program's Adult Treatment Panel III NCEP (ATP III) STEP-I diet recommendations.

Result: Repeated measures of anova revealed that both the groups has significantly lost their weight over time and, there was a strong time by group interaction (P=0.003). Mean reductions in waist circumference and waist/hip ratio also greater in the intervention group. During the intervention, there was a trend toward reduced body fat and visceral fat % in both the intervention and control group ($p<0.001$) and significant time by group interaction was observed for body fat % ($p<0.001$) & visceral fat % (p=0.007).

Conclusion: These findings indicated that intake of a high-fiber food especially soluble fiber (β-glucan) from barley should be strongly recommended to prevent the burden of chronic diseases.

Keywords: Metabolic syndrome, cardiovascular risk factors, barley, β-glucan, soluble fiber

Introduction

Metabolic syndrome is a complex web of metabolic risk factors that are linked with a 2-fold risk of CVD [1], 5-fold risk of diabetes [2] and fivefold increase in the mortality over a 5-10 year period [3]. There is strong evidence to suggest that Individuals with Metabolic syndrome have a 30%-40% likelihood of developing diabetes/ CVD within 20 years; depending on the number of components they have [4]. According to the National Cholesterol Education Program (NCEP) panel, metabolic syndrome will soon have a greater impact on premature coronary artery disease than tobacco (NCEP ATP III 2001) [5]. It is estimated that 20-25**%** of the world adult population suffer from metabolic syndrome disorders [6]. Prevalence of this syndrome is increasing dramatically throughout the world, not only in adult or older populations but also in children and young people running in parallel with the worldwide epidemic of obesity and diabetes. As with other chronic diseases, the prevalence of metabolic syndrome is increasing with current prevalence estimates in the Asia-Pacific region between 10% and 30% [7]. Nearly 30% of Indians have metabolic syndrome disorder (NIN 2010). The prevalence of metabolic syndrome is increasing exponentially in India, both in the urban and rural areas. Given the enduring outbreak of overweight and obesity, it is expected that the prevalence of the MS will continue to grow. Another study by Prasad *et al*. (2008) in India, reported the prevalence of metabolic syndrome is 33.5% overall, 24.9% in males and 42.3% in female [8].

These data highlight the urgent need for control of upstream causes of obesity (Excessive caloric intake, poor dietary habits and physical inactivity) to control the rapidly increasing epidemic of diabetes and coronary heart disease in India.

The National Cholesterol Education Program's Adult Treatment Panel III (ATP III) (2001) has developed guidelines for reducing the risk of CVD which strongly urge lifestyle modification, including dietary changes, as the foundation and initial intervention for persons at risk for CVD. An important component of the lifestyle modification is a 'heart-healthy' diet, which specifically includes a recommendation for consumption of at least 5-10 g viscous soluble fibre (VSF) per day. Recently, the US Food and Drug Administration (FDA), (2001) allows the health claim statement that, depending on the beta-glucan content, consumption of soluble fibre from barley in a diet may reduce the risk of CVD [9]. The high viscosity of β-glucan may be particularly effective at reducing postprandial glycemia and several trials using oat or barley products reported significant reductions in glycemic response [10]. The health claim was amended to allow inclusion of barley and barley products. Work conducted in a laboratory indicates that consumption of a diet rich in barley results in as great or even greater reduction in plasma cholesterol and other blood lipids [11]. In a review of the effect of fiber-rich carbohydrates on features of the Metabolic Syndrome, Davy and Melby (2003) [12] report that consumption of 20-35 g/day of total dietary fiber and at least 3 g/day of soluble fiber, as recommended by the American Dietetic Association, results in a reduction in risk factors for cardiovascular disease and diabetes [12]. Increasing the intake of whole grain products such as barley would increase both total and soluble dietary fiber in the diet and most likely would result in decreasing the risk factors for disease even in men and women already overweight. Most research on soluble fiber has focused on oats. Barley, another excellent soluble fiber source, has received little attention. Thus, research is needed to assess the health effects of human consumption of barley on risk factors associated with cardiovascular diseases.

Subject and Methods

Participants: The present study was performed at the Department of Cardiology, Sir Sunderlal Hospital Banaras Hindu University Varanasi (UP) India on an outdoor patient basis for 4 months. Overall, two hundred seventy eight men and women aged 30 and 70 year, with MS was recruited as Diagnosed according the definition given by the *(NCEP ATP III)* (Modified 2004). The inclusion criteria were as follows: Waist circumference (males: ≥90 cm and for females: ≥80 cm), Triglycerides ≥150 mg/dl (1.7 mmol/l), Low HDL (Males <40 mg/dl (1 mmol/l) and or females <50 mg/dl (1.3 mmol/l), Systolic blood pressure ≥130 mmHg and/or Diastolic blood pressure ≥85 mmHg. Fasting blood sugar ≥100 mg/ dl (5.6 mmol/l). To be enrolled in the study, patients had to have ≥3 of the above-mentioned criteria. Subjects were excluded if they were diagnosed with diabetes mellitus, cardiovascular diseases, chronic liver or kidney disease, advanced cancer or any other chronic disease. The present study was approved by the institutional ethics committee on biomedical research in humans of institute of medical sciences Banaras Hindu University Varanasi. And written informed consent was obtained from each of the participants.

Study design

This study was based on a randomized, single blind controlled, parallel group design. The whole study was conducted in three phases:

Phase I: Screening for eligibility and selection of subjects. Phase II. Stabilization Phase: Participants met all the above inclusion criteria eligible to enter in the diet stabilization phase. During the stabilization phase, all participants were instructed to eat a "background diet (control)" for 4 weeks. Detailed descriptions of the recommended diet during stabilization phase are given in Table 2. The dietary interventions were designed to be convenient and realistic for free-living individuals to achieve, with no strict recommendations in their usual lifestyle. Phase III. Randomization& 3 month Intervention. Participants still met all inclusion criteria were randomly allocated to one of two groups for a 12-week intervention period:

1. Intervention group: (Addition of barley foods containing soluble fibre (β-glucan) to the background diet menus.

2. Control group: (continuation of the background (control) diet NCEP- STEP I diet). Participants were advised not to change their usual lifestyle and medications unless necessary, throughout the trial. All the participants underwent clinical & biochemical investigations including blood pressure, anthropometry, and fasting blood profile at baseline (End of stabilization) 4, 8 and 12 weeks.

Nutritional strategy

The background diet was designed to be identical in both arms of the intervention to ensure that the only nutrient that differed between the groups was beta-glucan. All the participants were provided with different eating plans which was based on the NCEP STEP-I guidelines (total fat less than 30%, saturated fat 8-10%, protein approximately 10-15%, carbohydrate 55-60% of total calories and cholesterol< 200 mg/day). Total energy requirements were calculated by multiplying the physical activity level (PAL) with the resting metabolic rate (RMR). There was no attempt to limit energy intake or to maintain iso-caloric intake for each participants. This was achieved by making proportional reduction to all the foods mainly wheat & rice in the background diet to accommodate the energy supplied by the barley foods containing soluble fiber. The emphasis of the intervention diet was to consume soluble fibre (beta-glucan) as achieved primarily through consumption of barley.

Measurements

Body weight was measured while the subjects were minimally clothed without shoes by using the OMRON BODY FAT ANALYZER (HEF-200). Height was measured in a standing position, without shoes, by using a tape meter while the shoulders were in a normal state. Waist girth was measured as the narrowest circumference between the bottom of the rib cage and the iliac crest by using a un-stretched tape measure whereas; hip circumference was measured at the intertichantric level. Body composition was measured by bioelectrical impedance analysis (BIA) using the Body Composition Analyzer (OMRAN HEM-903).

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software (trial version 16). Continuous variables were expressed as mean ± standard deviation, and categorical variables (dichotomous variables) were expressed as frequencies and proportions (percent). All the continuous variables were assessed using the Kolmogorov-Smirnov Z test to examine the distribution type; if the data did not exhibit a normal distribution, either they were logarithmically transformed prior to analysis or the non-parametric tests were applied. For the normally distributed data, descriptive statistics & Independent-sample t-test with 95% confidence intervals was used for each measure to establish that there were no significant baseline differences between groups (Intervention vs. Control) for continous variables and Chi-square was used to assess the baseline differences between the Intervention and control group for categorical variables. In addition, Macnemar *chi square* tests were used to analyze the differences within groups from baseline to 3 month (12-weeks) for categorical variables. We also determined the mean percentage change differences, which were derived by calculating the differences in percentage change for each variable in pair-wise group comparisons. For all analyses, the level of statistical significance was set at p Z 0.05 (two tails). Average daily energy intakes were quantified from the data collected in the 24-hour recalls, using a standard exchange list based on the recommendation of the Indian council of medical research 2010. All food records were analyzed by a specially designed computerized program using the food database of Nutritive value of Indian foods (ICMR 2010).

Results

Overall two hundred five men & women successfully completed the trial. At baseline the 2 dietary groups were well matched for all physical characteristics and metabolic profile (Table 1). At the end of the study, body weight, BMI, waist girth, visceral fat systolic blood pressures, total cholesterol, serum triacylglycerol and blood glucose decreased significantly in the intervention group. (All the data not shown here).

Table 1: Mean anthropometric measurements and body composition at baseline (After stabilization).

Variables	Intervention group (n=104)	Control group (n=101)	t test/ P- value
	Mean ± SD	Mean ± SD	
Weight (kg)	68.7±11.3	66.7±11.1	0.19
Height (cm)	160.1±7.6	159.9±6.6	0.80
BMI(kg/m^2)	26.6±3.8	26.1±3.8	0.28
Waist (cm)	103.8±11.7	102.1±11.6	0.30
Hip (cm)	105.6±12.3	105.7±12.3	0.97
Waist/hip ratio	0.98±0.07	0.98±0.07	0.09
Total body fat %	31.2±5.7	31.7±5.4	0.57
Visceral fat %	12.2±5.3	11.7±5.4	0.51
RMR (Kcal /day)	1480±205	1460±235	0.51

The anthropometric measurements and body composition details of the subjects are mentioned in Table 1. When subjects were analyzed on the basis of anthropometric measurements and body composition, it was apparent from the table that mean body weight of the respondents was 68.7±11.3 and 66.7±11.1 and the mean of the waist/ hip ratio was 0.98±0.07 and 0.98±0.07 in the intervention and control group respectively. Although there was insignificant differences between the intervention and control group regarding any of the above measurements (p>0.05).

Table 2: Mean anthropometric measurements at baseline & magnitude of change throughout the trial.

Variables / group	Mean ± SD				Repeated measures of ANOVA		
	Baseline	Week 4	Week 8	Week 12	P for interactions		
					Time	Group	Group×time
Weight [kg]							
Intervention	68.7±11.3^a	68.0±11.1^b	67.1±11.0^c	66.0±10.9^{ab}	0.000	0.34	0.003
Control	66.7±11.1^a	66.1±11.0^{ab}	65.7±10.9^b	65.4±10.8^b			
BMI[kg/m^2]							
Intervention	26.6±3.80^a	26.4±3.74^b	26.0±3.73^c	25.6±3.70^{ab}	0.000	0.48	0.000
Control	26.1±3.86^a	25.8±3.83^{ab}	25.7±3.79^b	25.6±3.73^b			
Waist[cm]							
Intervention	103±11.7^a	103±11.7^a	102±11.1^b	101±11.2^{ab}	0.000	0.42	0.000
Control	102±11.6^a	102±11.6^a	101±11.5^b	101.4±11.4^{ab}			
Hip[cm]							
Intervention	105.9±12.3^a	105.1±12.1^b	104.9±12.2^b	104.7±12.3^{ab}	0.05	0.81	0.80
Control	105.7±12.3	105.7±12.1	105.1±12.0	105.1±11.8			
Waist/ hip ratio							
Intervention	0.98±0.07^a	0.98±0.71^a	0.97±0.68^a	0.96±0.07^b	0.000	0.09	0.03
Control	0.96±0.68^a	0.96±0.72^b	0.96±0.70^b	0.96±0.68^b			

P values for interactions were obtained by using a General linear model (GLM). Two-way repeated-measures ANOVA.
a, b mean values within a row with different superscript letters are significantly different. (Sidak multiple comparison adjustments $p<0.05$)

The mean values for body weight, body mass index, waist, hip circumference and waist hip ratio at baseline and during the trial are shown in Table 2. Repeated measures of anova revealed that both the groups has significantly lost their weight over time and the effect of time was significant *(p<0.001);* however, there was a strong time by group interaction (*P*=0.003), such that intervention group lost more weight in comparison to control group throughout the trial. Similarly for the body mass index and waist circumference, changes over time was significantly different among the groups as reflected by a significant time by group interaction (*p*<0.001). A significant time by group effect was also observed in the change in waist hip ratio (*P* =0.03), such that reduction was greater in the intervention group compared to control group. Significant effect of time was observed for all the anthropometric variables (*p*<0.001) with only the exception of hip circumference, effect of time was not significant (p=0.05), however reductions observed by groups were not significantly different for any of the variables. When the main effect of time was significant multiple comparison (Siadk multiple comparison adjustment) was applied to know where the differences actually lie, compared with the baseline values both the groups differed significantly at 12-weak except the hip circumference (Table 2).

Table 3: Mean change and mean % change in anthropometric measurements from baseline to end of the trial.

Variables	Intervention Group (n=104)		Control Group (n=101)		Between group difference			
	Baseline vs.12 week		Baseline vs.12 week		Intervention vs. control			
	Mean change	Mean % change	Mean change	Mean% change	for mean change		for mean% change	
					Mean. diff. (95%CI)	p[1]	Mean. diff. (95%CI)	p[2]
Weight [kg]	-2.71**	-3.91**	-1.22*	-1.78*	- 1.48 (-0.9, -2.0)	<0.001	-2.13 (-1.2, -2.9)	<0.001
BMI [kg/m²]	-1.04**	-3.89**	-0.48*	-1.78*	-0.56 (-0.3,-0.7)	<0.001	-2.11 (-1.2,-2.9)	<0.001
Waist[cm]	-2.39**	-2.25**	-1.11	-1.08	-1.27 (-0.5,-1.9)	<0.001	-1.16 (-0.5,-1.7)	0.001
Waist/hip ratio	-.016*	-1.61*	-.009	-0.92	-.007 (.001,-.01)	0.05	-0.01 (2.6,-2.6)	0.98

*Significant within-group change from baseline to 12-weak, (paired samples t -test). *P <0·05; **P, <0·001.
p[1] & p[2] values for comparisons of between-group changes (intervention vs. control). (Independent samples t -test.)

The Mean changes in anthropometric measurements from baseline to end of the dietary intervention are shown in Table 3. Mean body weight decreased by (-2.71) kg in the intervention group, significantly more than the (-1.22 kg) in the control group. The corresponding reductions in BMI were (-1.04) and (-0.48) kg/m^2 in the intervention and control group respectively. The between-group differences for body weight and body mass index were -2.13 kg (95% CI, −1.2 to −2.9, p<0.001) and -2.11 kg/m^2 (95% CI, −1.2 to −2.9, P<0.001). Mean reductions in waist circumference and waist/hip ratio were also significantly greater in the intervention group, compared with the control group.

We also looked out to analyze the mean % change in these variables from baseline to12-weak, it shows body weight and BMI was significantly decreased by (-3.91%) and (-3.89%) in the intervention group compared to (-3.89%) and (-1.78%) in the control group. The between-group differences proved significant for all variables apart from waist/hip ratio for mean % change, indicating that the recommended dose of barley in a daily diet was sufficient to significantly affect the anthropometric measurement in a three month.

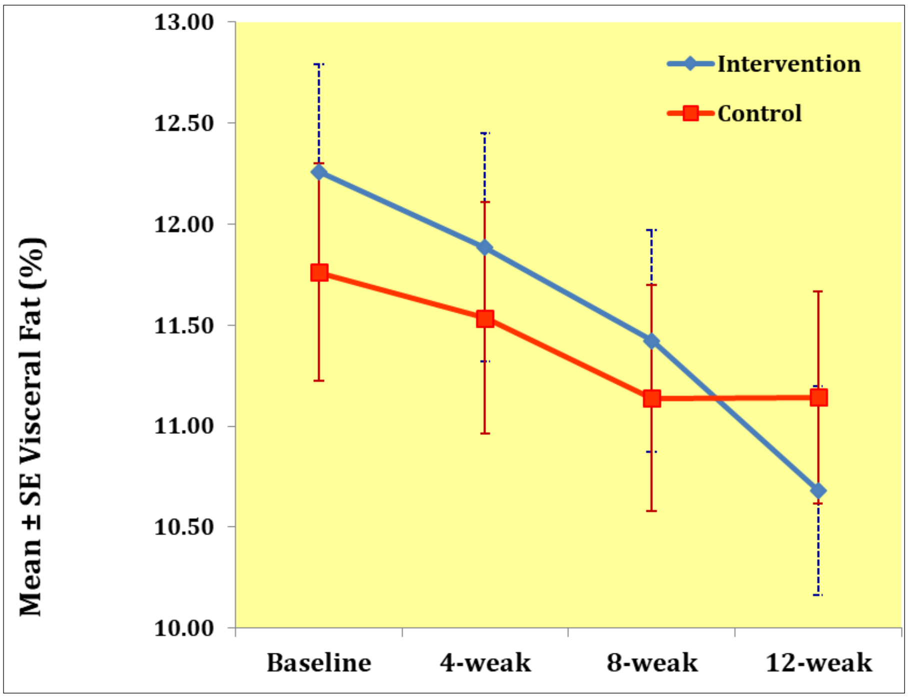
Table 4: Mean body fat % resting metabolic rate at baseline & magnitude of change throughout the trial

Variables / group	Mean ± SD				Repeated measures of ANOVA		
					P for interactions		
	Baseline	Week 4	Week 8	Week 12	Time	Group	Group× time
Total body fat [%]							
Intervention	31.2±5.74[a]	31.0±5.62[a]	30.4±5.36[ab]	28.9±5.59[b]	0.000	0.36	0.000
Control	31.7±5.48[a]	31.2±5.71[a]	30.5±5.60[b]	30.8±5.52[b]			
Visceral fat[%]							
Intervention	12.2±5.34[a]	11.8±5.67[a]	11.4±5.54[b]	10.6±51.10[b]	0.000	0.82	0.006
Control	11.7±5.46[a]	11.5±5.84[a]	11.1±5.63[b]	11.1±5.43[b]			
Resting Metabolic Rate[Kcal]							
Intervention	1480±205	1466±267	1464±240	1492±237	0.40	0.98	0.10
Control	1460±235	1428±206	1435±218	1467±238			

P values for interactions were obtained by using a General linear model (GLM). Two-way repeated-measures of ANOVA.
a, b mean values within a row with different superscript letters are significantly different. (Sidak multiple comparison adjustments p<0.05)

As shown in the (Table 4) during the intervention, there was a trend toward reduction of body fat and visceral fat % in both the intervention and control group and it significantly affected by the length of time (p<0.001). The reductions observed by group were not significantly different, whereas significant time by group interaction was observed for body fat % (p<0.001) & visceral fat % (p=0.007). It shows that over time changes were significantly higher in the intervention group as compared to control group. Although there was insignificant effect of time and time by group interaction was found for resting metabolic rate. Resting metabolic rate was fairly declined at 4 & 8 weak in both the groups and again it had returned to baseline levels at 12-weak of follow up.

Within group test indicated the mean changes in body fat and visceral fat % decrease significantly at 12 weak by (-2.36and -1.57) in the intervention group whereas it was (-0.85and-0.62) in the control group correspondingly. Compared with the control group, the intervention group resulted in a lower total body fat % by -2.36% (95% CI, -0.7 to -2.2 p<0.001) at week-12 and a visceral fat % by -0.95(95% CI, (-0.3 to 1.5 p=0.003). However, when we calculate the mean % change in body fat after the 12-weak, body fat% reduced by (-7.2%) compared to (-2.55%) in the control group similarly for the visceral fat mean % reductions was (-11.5%) and (-3.49%) in the intervention and control group.



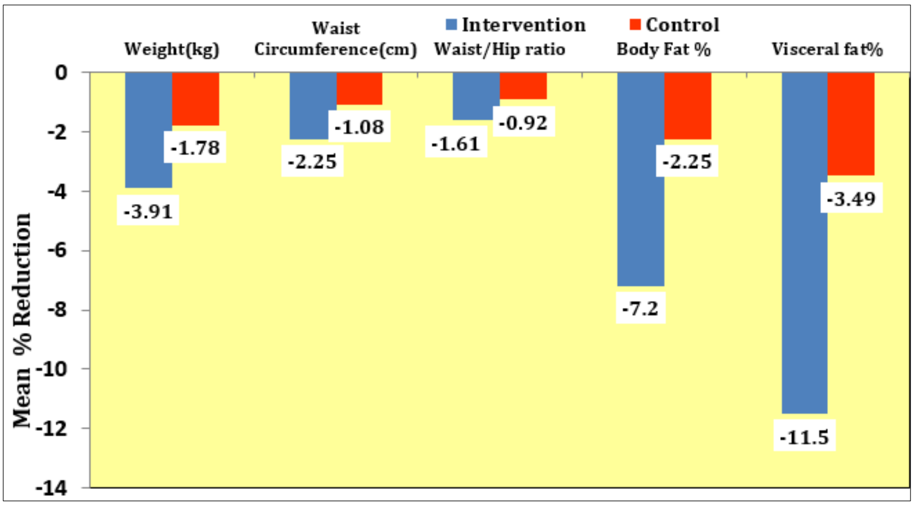
SE= Standard error

Fig 1: Trends showing the mean change in Visceral Fat throughout the trial.

Table 5: Mean change and mean % change in body fat and visceral fat from baseline to end of the trial.

Variables	Intervention Group (n=104)		Control Group (n=101)		Between group difference/ effect size			
	Baseline vs.12 week		Baseline vs.12 week		Intervention vs. control			
	Mean change	Mean% change	Mean change	Mean% change	for mean change		for mean% change	
					Mean. diff. 95%CI	P[1]	Mean. diff. ± 95%CI	P[2]
Total body fat [%]	-2.36**	-7.20**	-0.85**	-2.55**	-1.50 (-0.7,-2.2)	<0.001	-4.64 (-2.3,-6.9)	<0.001
Visceral fat [%]	-1.57**	-11.5*	-0.62*	-3.49*	-0.95 (-0.3,-1.5)	0.003	-8.08 (-1.8,14.3)	0.01

*Significant within-group change from baseline to 12-weak, (paired samples t -test). *P <0·05; **P, <0·001.
p[1] & p[2]values for comparisons of between-group changes (intervention vs. control). Independent samples t -test.



* Indicates the significant difference between the groups (Independent t-test)

Fig 2: Mean % Reduction in anthropometry & Body composition from baseline to end of the intervention (12-weak)

Discussion

This study compared the effects of whole grain barley as an adjunct to a normal, heart healthy diet in free-living, men and women with metabolic syndrome. After 12 weeks of intervention with barley, intervention group significantly decreased body weight compared to control group. Mean body weight decreased by (-2.71) kg in the intervention group, significantly more than the (-1.22 kg) in the control group. Barley recommended in this study was whole grain and suggested intake was about 4-6 servings per day on the basis of individual calorie requirement. The corresponding reductions in BMI were (-1.04) and (-0.48) kg/m^2 in the intervention and control group respectively. Mean reductions in waist circumference and waist/hip ratio were also significantly greater in the intervention group, compared with the control group. Similarly, Keenan *et al.* (2007) compared the effects of two concentrated barley β-glucans in a self-selected diet in mildly hypercholesterolemia men and women and after six weeks of supplementation with higher molecular weight barley fiber significantly decreased body weight. Reduction in body weight was unwanted result in this study; because there was no calorie restriction in the present study. Significant decrease in weight with the barley diet may have been attributable to a high amount of dietary fiber.

Although in this study, subjects were not requested to do not change their usual physical activity programs because of ethical issues and subjects may have increased activity as the study progressed. Previous research suggests that consuming the recommended amounts of dietary fiber may reduce energy intake as a result of reduced hunger and thus lead to weight loss [13]. Epidemiological studies tend to show that fiber is associated with reduced long-term weight gain [14], [15]. Clinical trials of soluble fibers find conflicting results. Kovacs *et al.* (2007) fed soluble guar gum to overweight males on an energy-restricted diet. These subjects had significant decrease in their body weight and body fat percentages with no increase in hunger, although calories were restricted. Hunger at lunch was significantly reduced from baseline with consumption of barley in this study. Body weight (kg) decreased significantly from baseline to 12 weeks in the intervention group. This is interesting because there was no reported difference in nutrient intake from baseline to the end of the study.

Although the effect of barley or oats on visceral fat was not known. During the intervention, there was a trend toward reduced body fat and visceral fat % in both the intervention and control group and it significantly affected by the length of time ($p<0.001$). The reductions observed by group were not significantly different, whereas significant time by group interaction was observed for body fat % ($p<0.001$) & visceral fat % ($p=0.007$). According to the 2006 exercise guide from the Ministry of Health, Labour and Welfare, a 1-kg reduction of body weight induced by moderate exercise for the visceral fat loss corresponds to a 1-cm reduction of waist circumference [15]. In another trial, Lierz G *et al.* (2002) reported the net change of body weight in the test group at week 12 was correlated not with the reduction of the visceral fat area ($r=0.065$, $P=0.791$) but with that of the subcutaneous fat area ($r=0.618$, $P=0.005$) [16]. This suggests that the mechanism of the visceral fat reduction due to barley intake might be different from that of the weight loss due to exercise. The mechanism by which visceral fat is reduced thus seems to differ from the mechanism by which serum cholesterol levels are reduced and might vary with the genetic backgrounds of the subjects [17]. The low glycemic index of barley, which affects the lipid metabolism, might be one of the mechanisms of visceral fat reduction by barley intake. And barley contains other components than β-glucan that might affect lipid metabolism. Further research will be required to clarify the mechanisms by which barley reduces visceral fat. In conclusion, barley intake significantly and safely reduced visceral fat area, BMI, and waist circumference. Barley with high amount of β- glucan has beneficial effects in preventing the metabolic syndrome [7].

Conclusion

This study demonstrates that incorporating whole grain barley into a normal diet can lead to significant improvements in body weight, BMI, waist circumference, and waist/hip ratio among individuals with metabolic syndrome. The findings suggest that the high dietary fiber content of barley may contribute to reduced hunger and subsequent weight loss, despite no imposed calorie restriction. While the study did not directly measure visceral fat reduction, trends observed suggest potential benefits in this area. Further investigation into the specific mechanisms by which barley affects lipid metabolism and visceral fat reduction is warranted to fully understand its therapeutic potential in managing metabolic syndrome.

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