Research Article

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Effects of Kale (*Brassica oleracea var. acephala*) Consumption on Anthropometric Markers of Adiposity among Adults with Metabolic Syndrome

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Abstract

Kale (*Brassica oleracea var. acephala*) contains nutrients and phytochemicals linked to a lower risk of metabolic syndrome. This randomized controlled trial examined the effect of kale ingestion on adiposity markers including body weight, BMI, waist circumference, body fat, and visceral fat percentages in 78 adults with metabolic syndrome over 8 weeks. Participants were divided into two groups by stratified random sampling. The 38 participants in the experimental group received 70g of fresh kale daily, while a placebo containing 250 mg of corn starch was given to 40 participants in the control group. Throughout the intervention, from baseline to week 8, dietary records showed that percentage changes in vitamin A, B2, C, E, and calcium intake were significantly greater in the experimental group than in the control group, while changes in energy intake and expenditure between the groups were not significantly different. Comparing anthropometric markers revealed a significant decrease in waist circumference in the experimental group compared to baseline. However, body weight, BMI, body fat percentage, and visceral fat percentage did not show significant differences within or between the groups. The results suggest that daily ingestion of 70g of kale may reduce waist circumference and could be considered an alternative method for preventing metabolic syndrome.

Keywords: Kale (*Brassica oleracea var. acephala*), Anthropometric marker, Adiposity

What was Known

- Dietary management through kale intake may help reduce body fat.
- Kale consumption may be an alternative strategy for obesity prevention and control.

What's New and Next

- Kale consumption may reduce waist circumference in adults with metabolic syndrome.
- Future research should extend the study duration to explore long-term effects on body composition.

Introduction

Obesity or excess fatness is a risk factor for metabolic syndrome (MetS), which is closely linked to noncommunicable diseases (NCDs) such as diabetes, hypertension, cardiovascular diseases, cancer, and others. Consequently, both MetS and NCDs contribute significantly to mortality worldwide.[1, 2] These issues directly affect people's well-being and place a burden on public healthcare systems.

Anthropometric markers of adiposity are efficient tools for evaluating health or nutritional status and identifying obesity. The main components of anthropometric markers include body weight, body mass index (BMI), waist circumference, body fat percentage, visceral fat percentage, among others. Excessive body fat, commonly found in individuals with overnutrition, is a major risk factor for MetS.[3] According to the International Diabetes Federation (IDF) criteria, individuals can be diagnosed with MetS if they have abdominal obesity, defined as a waist circumference ≥ 90 cm for men or ≥ 80 cm for women, along with any two of the following signs: high blood pressure > 130/85 mmHg, high fasting blood sugar > 100 mg/dL, high triglycerides > 150 mg/dL, or low HDL-C < 40 mg/dL in men and < 50 mg/dL in women.[4]

Increasing physical activity, balancing the diet, and increasing fruit and vegetable consumption are effective ways to manage and reduce the risk of obesity. Several studies have found that kale (Brassica oleracea var. acephala) contains low calories and rich in various micronutrients, vitamins C, E, A, K, as well as magnesium, potassium, including dietary fiber can be found.[5, 6] Moreover, kale contains bioactive compounds such as glucosinolates, phenolic compounds, plant sterols (sitosterol), and flavonoids (quercetin and kaempferol), which have the potential to improve obesity and MetS.[7, 8] Some studies have shown that fiber-rich vegetables like kale play a potential role in supporting a healthy microbiome for weight management.[9] Kale

may be an alternative food for improving and preventing MetS. Therefore, we aimed to investigate the effect of kale consumption on anthropometric markers of adiposity in adults with MetS.

Materials and Methods

A randomized controlled trial (RCT) was conducted in this experimental study to examine the differences in anthropometric markers of adiposity between the experimental group (fresh kale consumption) and the control group (placebo), as well as within each group at baseline (week 0) and after 8 weeks of intervention.

Populations and samples

Males and females aged between 25 and 59 years who lived in Bangkok and the surrounding areas were invited for metabolic syndrome screening. A total of 80 adults with MetS were recruited. Participants were randomly divided into two equal groups using stratified systematic sampling. Unfortunately, two adults in the experimental group dropped out during the intervention; therefore, in experimental group and control group were 38 and 40 subjects, respectively.

Data collection

Anthropometric markers of adiposity, including body weight (kg), height (cm), BMI, body fat percentage, and visceral fat percentage, were assessed using the Bioelectrical Impedance Analysis (BIA) technique with a Tanita DC-360 apparatus. Waist circumference was measured with a measuring tape. The data collection for this section was conducted at the Faculty of Public Health, Mahidol University, and all measurements were carried out by the research team. The participant compliance rate for these assessments was 100%. Dietary intake assessments were conducted through 3-day dietary records, collected on 2 weekdays and 1 weekend day. The dietary data were collected at baseline (week 0) and after 8 weeks. All participants were required to describe the type and quantity of all foods and drinks consumed. These records were completed by the participants themselves and consistently followed up by the research team via the LINE communication platform. This consistent monitoring ensured a 100% compliance rate among participants and prevented any data loss during the collection process. The data were then analyzed using the INMUCAL program, developed by the Institute of Nutrition, Mahidol University.

For physical activity assessment, participants' activities were recorded using a questionnaire on 2 days at baseline (week 0) and at week 8. Metabolic Equivalents (METs) were used to analyze physical activity levels.[10]

Effective dose (fresh kale consumption)

Based on the in vivo results of kale extract's biological activities in reducing cholesterol and blood lipids[11] and the recommended daily vegetable intake for adults[12], participants in the experimental group were advised to consume one cup (70g) of fresh kale daily, provided and distributed by No Bitter Co., Ltd., Thailand.

Research procedure

Fresh kale was delivered to the homes of participants in the experimental group weekly. They were instructed to divide the kale into 70g portions to be consumed daily for 7 days. Cooking instructions, recommended menus, and preservation guidelines were provided to participants. They were required to take a picture of their meal and report to the researchers daily via the Line application to ensure compliance with the kale consumption. Participants were also instructed to report any instances of poor-quality kale, which would be replaced with fresh, good quality kale.

Participants in the control group received a single supply of 60 placebo capsules, each containing 250 mg of corn starch. They were instructed to consistently consume one capsule daily for 8 weeks.

Both groups were monitored for dietary intake and physical activity. All participants were consistently reminded and monitored through the Line application.

Statistical analysis

Non-parametric Chi square ($\chi 2$) test was used to analyze the demographic characteristics data, while the comparison of dietary intake and energy expenditure from physical activities within and between the experimental and control groups, which were found to be non-normally distributed were analyzed using the Mann-Whitney test and the Wilcoxon Signed Ranks test, with significance set at 95% confidence intervals (CI).

Anthropometric markers of adiposity between the two groups were analyzed using parametric independent samples t-test, while a paired samples t-test was used to compare within the experimental group and control group, as the data were normally distributed. Statistical significance was set at a 95% confidence interval (CI).

Results

All demographic data, including age, sex, level of education, alcohol consumption, and place of residence of all participants, were collected and evaluated using the Chi-square test, with a significance level of 0.05 for the p-value. All demographic data no difference significant decrease as demonstrated in Table 1. The comparison of energy and dietary intake data during the intervention within the fresh kale group revealed a significant decrease in both the amount and percentage of protein consumption, while vitamin A, vitamin C, and calcium intake significantly increased. In the placebo group, there was a significant decrease in energy intake, as well as in the amounts of protein, fat, dietary fiber, and calcium intake (data is not shown). Table 2 shows the comparison of change and percentage changes in dietary intake data between both groups. It demonstrated significant differences in vitamin A, vitamin B2, vitamin C, vitamin E, and calcium, with these nutrients being higher in the experimental group compared to the control group. Similarly, the comparison of physical activities between the two groups, as well as within the individual experimental and control groups, showed no significant differences (data is not shown).

The anthropometric markers between the experimental group and the control group were not significantly different. Similarly, the comparison of anthropometric data within the control group showed no significant differences (data is not shown). However, a significant decrease in waist circumference was observed in the experimental group at week 8, the average values presented represent the combined average of both genders as demonstrated in Table 3.

Table 1 Demographic data between fresh kale and placebo group at baseline (n = 78)

Demographic data	Fresh kale group (n=38)		Placebo group (n=40)		*p*-value
	n	%	n	%	
Age (year)					0.268
25 – 34	3	7.9	7	17.5	
35 – 44	11	28.9	14	35.0	
45 – 54	18	47.4	17	42.5	
≥ 55	6	15.8	2	5.0	
Mean ± SD	46.6 ± 7.7		43.2 ± 7.9		
Sex					0.452
Male	6	15.8	9	22.5	
Female	32	84.2	31	77.5	
Level of education					0.377
High school and lower	14	36.8	11	27.5	
Above high school	24	63.2	29	72.5	
Alcohol consumption					0.102
Drink	1	2.6	5	12.5	
Never	37	97.4	35	87.5	

Remark: *p*-value from χ^2

Table 2 Energy and dietary intakes data change and percentage change between fresh kale and placebo group (n = 78)

Dietary intake data	Fresh kale group (n = 38) Median (IQR)	Placebo group (n = 40) Median (IQR)	*p*-value
Energy (kcal)			
Change	-51.9 (-333.5-245.5)	-173.2 (-346.4-102.5)	0.299
%Change	-2.9 (.19.5-17.9)	-13.9 (-24.7-6.4)	0.139
Carbohydrate (g)			
Change	-13.3 (-58.6-22.4)	-13.2 (-46.6-19.8)	0.899
%Change	-7.1 (-25.5-16.4)	-14.0 (-25.5-12.5)	0.600
Carbohydrate (%)			
Change	-2.7 (-5.4-4.9)	0.2 (-6.0-5.6)	0.421
%Change	-5.9 (-10.9-10.1)	0.4 (-10.9-11.3)	0.375

Table 2 Energy and dietary intakes data change and percentage change between fresh kale and placebo group (n = 78) (Cont.)

Dietary intake data	Fresh kale group (n = 38) Median (IQR)	Placebo group (n = 40) Median (IQR)	*p*-value
Protein (g)			
Change	-10.1 (-19.8-4.7)	-6.8 (-22.6-4.5)	0.960
%Change	-13.5 (-27.3-3.4)	-9.8 (-35.8-6.8)	0.963
Protein (%)			
Change	-2.3 (-3.9-1.3)	-0.7 (-3.1-2.1)	0.163
%Change	-12.3 (-24.0-10.3)	-3.8 (-18.1-12.9)	0.211
Fat (g)			
Change	5.5 (-17.7-15.7)	-6.2 (-19.0-6.4)	0.097
%Change	6.7 (-23.6-25.9)	-15.4 (-33.8-8.6)	0.102
Fat (%)			
Change	3.8 (-2.8-8.2)	-0.4 (-5.1-4.8)	0.059
%Change	9.9 (-10.9-25.2)	-1.6 (-17.1-15.1)	0.137

Table 2 Energy and dietary intakes data change and percentage change between fresh kale and placebo group (n = 78) (Cont.)

Dietary intake data	Fresh kale group (n = 38) Median (IQR)	Placebo group (n = 40) Median (IQR)	*p*-value
Dietary Fiber (g)			
Change	0.8 (-2.6-5.1)	-1.2 (-3.7-1.4)	0.097
%Change	-7.9 (-33.5-74.9)	-13.2 (-37.5-22.3)	0.265
Vitamin A (RE)			
Change	185.0 (-14.0-340.4)	-22.1 (-220.6-227.9)	0.044
%Change	50.6 (1.9-147.0)	-11.5 (-72.1-70.7)	0.012
Vitamin B1 (mg)			
Change	-0.1 (-0.4-0.3)	-0.2 (-0,6-0.1)	0.466
%Change	-8.5 (-43.8-20.7)	-10.9 (-56.8-17.6)	0.654
Vitamin B2 (mg)			
Change	0.1 (-0.2-0.4)	-0.1 (-0.4-0.2)	0.016
%Change	12.2 (-22.5-53.1)	-14.6 (-47.4-23.8)	0.010

Table 2 Energy and dietary intakes data change and percentage change between fresh kale and placebo group (n = 78) (Cont.)

Dietary intake data	Fresh kale group (n = 38) Median (IQR)	Placebo group (n = 40) Median (IQR)	*p*-value
Vitamin C (mg)			
Change	45.4 (2.9–72.0)	-4.7 (-17.3–13.8)	< 0
%Change	92.3 (-3.3–290.8)	-18.1 (-50.8–68.7)	0.003
Vitamin E (mg)			
Change	0.9 (-0.8–1.7)	-0.05 (-1.1–0.5)	0.048
%Change	34.7 (-23.9–93.3)	-13.6 (-60.9–60.2)	0.042
Calcium (mg)			
Change	155.5 (5.5–226.9)	-109.8 (-193.7–58.1)	< 0
%Change	35.5 (1.2–76.6)	-31.4 (-56.5–11.0)	< 0
Iron (mg)			
Change	0.04 (-2.1–3.6)	-1.2 (-4.7–1.9)	0.113
%Change	-4.1 (-22.3–66.7)	-13.9 (-38.8–34.6)	0.145

Table 2 Energy and dietary intakes data change and percentage change between fresh kale and placebo group (n = 78) (Cont.)

Dietary intake data	Fresh kale group (n = 38) Median (IQR)	Placebo group (n = 40) Median (IQR)	*p*-value
Potassium (mg)			
Change	-140.5 (-478.9-196.5)	-37.7 (-480.2-342.1)	0.791
%Change	-9.7 (-29.3-6.6)	-16.1 (-35.8-28.3)	0.832
Sodium (mg)			
Change	-247.8 (-1255.7-1078.0)	-106.4 (-1341.4-1270.6)	0.888
%Change	-14.1 (-31.7-24.8)	-2.1 (-37.2-45.9)	0.471

Remark: *p*-value from Mann Whitney test, significant at 95%CI

Table 3 Anthropometric data at baseline and after 8 weeks of fresh kale group (n = 38)

Anthropometric	Baseline	After 8 weeks	*p*-value
	Mean ± SD	Mean ± SD	
Weight, kg	67.5 ± 11.8	67.7 ± 12.2	0.342
BMI, kg/m^2	26.7 ± 4.3	26.8 ± 4.4	0.434
Waist, cm	93.7 ± 9.5	92.7 ± 10.2	0.046
Body fat, %	35.9 ± 6.1	35.8 ± 6.7	0.775
Visceral fat, %	8.5 ± 2.9	8.4 ± 3.0	0.324

Remark: *p*-value from Paired Sample t-test, significant at 95%CI

Discussion

This study investigated the effects of kale consumption on anthropometric markers of adiposity in adults with metabolic syndrome. Consuming 70 grams of fresh kale daily for eight weeks significantly reduced waist circumference, despite no significant change in energy intake and a slight increase in fat consumption

On the other hand, when the estimated changes in anthropometric markers within each group during the intervention were reviewed, no significant differences were found in the placebo group. Even though participants in the experimental group did not adequately control their physical activities and dietary intake—consuming a high-fat diet along with lower energy expenditure—the comparison of body composition between week 0 and week 8 showed a significant decrease in waist circumference in this group. This interventional study provides insight into the relationship between increased fresh kale consumption and a reduction in waist circumference. This reduction is correlated with decreased subcutaneous adipose tissue (SCAT) and visceral adipose tissue (VAT), which are linked to health improvements, including reduced risk of MetS.[13] However, changes in SCAT and VAT were not observed in this study due to the limited duration, which may have been insufficient to detect significant weight loss.[14]

Despite this, the reduction in SCAT and VAT associated with kale consumption is likely related to the elevated intake of dietary fiber, certain micronutrients like calcium, and phytochemicals such as flavonoids. Dietary fiber helps to lower cholesterol by binding to it in the

gut, resulting in a hypocholesterolemic effect. Soluble fiber may increase bile acid production from cholesterol in the liver, which is then excreted in the feces. Furthermore, dietary fiber is fermented in the colon by healthy gut microbiota, producing short-chain fatty acids (SCFAs) such as propionate, a precursor that inhibits cholesterol synthesis via succinyl-coenzyme A.[15] Dietary fiber also reduces lipid absorption and suppresses appetite, aiding in the improvement of obesity.[16] Several mechanisms have been proposed for how dietary fiber assists in weight management, including promoting satiety, reducing the absorption of macronutrients, and altering the secretion of gut hormones.[16] Metabolites, including SCFAs from dietary fiber fermentation in the gastrointestinal tract, are associated with decreased hunger and prolonged satiety. These metabolites regulate appetite by stimulating endocrine signals in the gastrointestinal tract, which are transmitted to the brain. As a result, hormones like cholecystokinin, glucagon-like peptide-1 (GLP-1), and peptide YY are secreted by enteroendocrine cells, reducing hunger and increasing satiety, ultimately leading to reduced food intake and weight loss.[17] Flavonoids positively influence lipid metabolism by improving glucose transport in adipocytes and increasing beta-oxidation, glycolysis, and ketogenesis, which regulate adipocyte synthesis.[18] Calcium plays a role in adipocyte accumulation and catabolism, as parathyroid hormone (PTH) and 1,25-hydroxy vitamin D regulate intracellular calcium. High calcium intake suppresses PTH and 1,25-hydroxy vitamin D, inhibiting lipogenesis and increasing lipolysis.[19]

This interventional study aligns with recent research, such as the study by Tomomi Ide, Asahi Suzuki, et al.[20], its study investigated the impact of kale powder consumption on individuals with potential metabolic syndrome, finding significant improvements in blood pressure, abdominal circumference, LDL-C, HDL-C, and fasting blood sugar level after 8-week intervention, and the study by Soo Yeon Kim, et al.[11], the study found that daily consumption of kale juice for 12 weeks improved coronary artery disease risk factors in men with high cholesterol. This study aligned with both study in highlighting kale's health benefits but differs in its randomized controlled trial design with a placebo. While this study focused on waist circumference reduction and nutrient intake, Tomomi Ide, Asahi Suzuki, et al. examined adiposity markers, and Soo Yeon Kim, et al. focused on cholesterol improvements, respectively. The reduction in abdominal or waist circumference observed in the experimental group after kale consumption may provide further understanding of how kale ingestion can improve MetS. However, the generalizability of this research was limited by the duration of the intervention.

According to previous studies on weight management[21], an eight-week intervention may be too short to observe significant changes in body composition. We recommend extending the intervention period to at least three months for future studies. Additionally, since this interventional study was conducted with free-living participants, the researchers could not fully control their diets and physical activities. Therefore, daily energy and dietary intake, as well as physical activities, should be standardized across participants in both groups in future studies to ensure greater reliability. Another limitation of this study is the gender imbalance, with 32 females and only 6 males. Future research may consider including participants of a single gender or ensuring a balanced gender ratio to improve the validity and generalizability of the findings.

Conclusion

This experimental study, a randomized controlled trial, investigated the effects of kale consumption on body composition in adults with MetS. The randomized 38 participants in the experimental group consumed 70g of fresh kale per day, while 40 participants in the control group consumed one placebo capsule daily for 8 weeks. Subsequently, the differences in anthropometric markers (body weight, BMI, waist circumference, body fat percentage, and visceral fat percentage) between both groups were analyzed and revealed. The change of intake of vitamins A, C, B2, E, calcium, and potassium in the experimental group was significantly higher than in the control group. Additionally, although the percentage changes in energy intake and energy expenditure were not significantly different between the groups, the results demonstrated that consuming 70g of fresh kale per day led to a decrease in waist circumference. This suggests that kale consumption may be a viable alternative for the prevention of obesity.

Ethical Approval Statement

This study was approved by the Ethical Review Committee for Human Research, Faculty of Public Health, Mahidol University (COA No. MUPH 2022-137), under Protocol No. 141/2022. The approval was granted on 17 October 2022, and the ethical clearance will expire on 16 October 2023. The project has been reviewed and approved according to the Declaration of Helsinki.

Author Contributions

Assoc. Prof. Dr. Patcharanee Pavadhgul conceptualized and designed the study. Lect. Dr. Jirayu Lainampetch and Mr. Wisanuwong Prasertkhongkha assisted in the development of the research methodology, including the randomization process, data collection tools, and the

dietary intervention plan. Data collection, including anthropometric measurements and dietary intake assessments, was carried out by Mr. Wisanuwong Prasertkhongkha under the supervision of Assoc. Prof. Dr. Patcharanee Pavadhgul and Lect. Dr. Jirayu Lainampetch. Statistical analyses were performed by Mr. Wisanuwong Prasertkhongkha with guidance from Assoc. Prof. Dr. Patcharanee Pavadhgul and Lect. Dr. Jirayu Lainampetch. The manuscript was drafted by Mr. Wisanuwong Prasertkhongkha and critically revised by Assoc. Prof. Dr. Patcharanee Pavadhgul and Lect. Dr. Jirayu Lainampetch. All authors approved the final version of the manuscript and agreed to be accountable for all aspects of the work in ensuring the accuracy and integrity of the research.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this article. No financial, professional, or personal relationships with any organizations or individuals influenced the research results or their interpretation.

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