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Original Article

Anti-inflammatory effects of plant-based Thai diets in overweight and obese individuals

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Abstract

This study aimed to determine the anti-inflammatory and health-promoting effects of plant-based Thai diets on overweight and obese individuals. This was a prospective, clinical study to enroll overweight and obese individuals, randomly assigned to consume either plant-based Thai diets as a nutrition intervention group or maintain their lifestyle diet group for 12 weeks. The plant-based Thai diet group had significantly greater mean reduction than the control, with different changes from the hsCRP level baseline ($p=0.0288$) and homocysteine level ($p=0.002$). Plant-based Thai diets significantly decreased diastolic blood pressure, total cholesterol, triglyceride, HbA1C level and TG/HDL ratio during the 12-week visit ($p<0.05$). In addition, the plant-based Thai diet group showed a statistically significantly greater decrease in body weight, BMI, waist-to-hip ratio, percent body fat, fat mass and lean mass, compared with the control. The consumption of plant-based Thai diets demonstrated the reduction of inflammatory markers, hsCRP and homocysteine level and weight control effects.

Keywords: plant-based Thai diets, overweight, obese, anti-inflammatory

1. Introduction

Overweight and obesity are a significant health problem worldwide, including in Thailand (World Health Organization [WHO], 2018). As for the ranking of obesity in the ASEAN region, Thailand came the second rank (32.6%) behind Malaysia (42.5%), with the highest proportion of people with this disorder (WHO, 2018). Being overweight or obese is associated with chronic inflammation (Harford, Reynolds, McGillicuddy, & Roche, 2011). A persistent inflammatory condition in obesity leads to chronic illnesses. Abnormal endocrinological response and irreversible immune disturbances caused by overweight or obesity directly increased metabolic and cardiovascular disease risk (Bays *et al.*, 2008). Similarly, prolonging fat accumulation to subcutaneous and visceral adipose cells stimulates pro-inflammatory cytokines and inflammatory cell activation. Chronic inflammation then worsens later. Chronic inflammation directly accelerates aging change, non-communicable diseases, and importantly harms their longevity (Howcroft *et al.*, 2013). Reducing chronic inflammatory process can help a person live longer and have a substantially healthier life (Howcroft *et al.*, 2013).

High sensitivity C-reactive protein, hsCRP is a serum biomarker for inflammation, including arterial inflammation. Previous studies indicated male subjects with high hsCRP levels (2 mg/L or higher) representing chronic inflammation had a three times greater risk of acute cardiovascular events and twice the risk of cerebral stroke than those with hsCRP level <2 mg/L (Chaudhuri *et al.*, 2013; Emerging Risk Factors *et al.*, 2010). Serum

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homocysteine is another biomarker for chronic inflammation. Elevated homocysteine levels compared to normal indicate impaired fasting plasma glucose, increased risk of bone mineral disorder, neuro-cognitive impairment and autoimmune diseases (Chellappa & Ramaraj, 2009).

Standard treatment for overweight and obesity includes lifestyle modification, diet control, regular exercise, anti-obesity medications, and surgical intervention. Nutrition intervention is an interesting new approach to the treatment of overweight and obesity because it is practical and inexpensive, and has less adverse effect compared to anti-obesity medication or surgery.

Plant-based diet represents a method of eating mainly of plant-origin foods in entire form (Hever & Cronise, 2017). A whole-food, plant-based diet also includes vegetables, fruits, whole grains, legumes, nuts, seeds, herbs and spices (Hever, 2016; Hever & Cronise, 2017). Modification of plant-based diet by eating at least 1,000 kcal per day from the source of plant-based whole-food is acceptable and adequately nutritious (McDougall & McDougall, 2013). A meta-analysis study to investigate the effects of a plant-based diet on inflammatory markers in overweight individuals showed that participants taking a plant-rich diet had a significant reduction of inflammatory markers by C-reactive protein (CRP) and interleukin-6 level than those not taking a plant-rich diet (Eichelmann, Schwingshackl, Fedirko, & Aleksandrova, 2016). A study by Yu *et al.* enrolled 67,211 women and 55,474 men living in Shanghai, China, and concluded that high fruit consumption could reduce cardiovascular risk compared to a non-high fruit diet (Yu *et al.*, 2014). Another study by Huang *et al.*, which combined the results of 12 different experimental trials, found that vegetarian dieters lost significantly more weight than non-vegetarian dieters (Huang, Huang, Hu, & Chavarro, 2016).

Traditional Thai cuisine typically includes plenty of herbs, spices, and superfoods rich with antioxidants, phenolic and flavonoid compounds (Tharasena & Lawan, 2014). Thai dishes comprise mainly plant-based whole foods such as stir-fried vegetables, spicy salads, hot pot, and mixed vegetables soup. Charoenkiatkul *et al.* reported that Thai dishes enriched with high calcium and precious trace elements such as phosphorus and magnesium Thai foods also had anti-thrombotic, fibrinolytic, blood pressure-lowering, anti-carcinogenesis and anti-oxidative properties (Charoenkiatkul, Kriengsinyos, Tuntipopipat, Suthutvoravut, & Weaver, 2008).

Because of the extensive health-related properties of plant-based Thai foods, the objective of this study was to determine the anti-inflammatory, weight reduction, glycated hemoglobin and lipid profile effects of plant-based Thai diets in overweight and obese individuals.

2. Materials and Methods

2.1 Research design and population

This study conducted at Mae Fah Luang University Hospital, Bangkok, Thailand. Overweight and obese subjects, body mass index (BMI) ≥ 23 kg/m², percent body fat ≥32% for female and ≥26% for male, aged 20-60 years with hsCRP level range between 1-12 mg/L were enrolled. Subjects were excluded if they were currently taking hypolipidemic drugs, had a history of chronic diseases (cardiovascular, diabetes mellitus, chronic renal or liver disease or eating disorder), were currently taking herbs or dietary supplements, cigarette, or were alcohol dependent. The sample size was calculated using two means comparison formula with type I error (α) of 5%, type II error of 10%. A total of 40 participants per group was used in this study.

This study was an unblinded, randomized-controlled, experimental trial. All study participants were randomly assigned using permuted-block randomization technique to receive either a nutrition intervention (NI), the experimental group, or to maintain their lifestyle (ML) control group. The nutrition intervention group was assigned to consume plant-based Thai diets for 12 weeks. All subjects in the nutrition intervention group were provided daily with plant-based Thai diet dishes with three-served meals, including snacks. Total calories per day were approximately 1,500-1,700 kcal with the three served meals. Dietary calories included 20-30% of protein, 30-35% of fat, and 40-45% of carbohydrate, and aimed to provide 30-40 grams of fiber daily. The ratio of dietary composition by weight basis was set with a ratio of 1:2:3 (protein to fat to carbohydrate). The energy and nutrient contents used in this study were adopted from the Joslin clinical nutrition guideline for overweight and obese adults with type 2 diabetes, prediabetes or those at high risk for developing type 2 diabetes (Hamdy, Ganda, Maryniuk, Gabbay, & Members of the Joslin Clinical Oversight, 2018).

The dishes were prepared under the supervision of the study investigators and qualified nutritionists using specific food recipes of the Institute of Nutrition, Mahidol University. These dishes consisted mainly of vegetables, fruits, tubers, whole grains, legumes, herbs, and spices. All dishes excluded all red meat and minimized white meat, such as chicken, fish, eggs as well as highly refined foods like bleached flour and refined sugar ingredients. The nutrition intervention group ate only the foods that were delivered to them daily. There were approximately 40 plant-based Thai diets menus in this study, but the emphasis was on the four main menus which the study participants ate 4 times per week throughout the 12 weeks experimental program. These food intakes of strongly anti-inflammatory diets were equal to 16 meals (4x4) per week out of a total of 21 meals (3x7) per week. The 12 weeks Plant-based Thai Diets focuses on 4 main menus each served 4 times a week and composed.

1. Stir-fried chicken in red curry (Phad Ped Kai) with 1 cup of berry rice and three cups of blanched cabbage.

2. Pineapple yellow curry with fish (Keang-hleung Thai Southern Style) served with 1 cup of berry rice and 200 g of fresh pineapple.

3. Steamed fish cake with Red Curry with Indian mulberry leaves (Hor Mok Pla Chon Bai Yor) with 1 cup of berry rice and 3 cups of blanched cabbage.

4. Shrimp Paste Tempeh Dip (Nam Prik Long Rua), two cups of mixed vegetables, and 1 cup of berry rice.

The rest of the meals, snacks, and herbal drinks throughout the 12-weeks programs were anti-inflammatory plant-based ingredients including red onion or shallot, garlic, chili, turmeric, coriander, black pepper, lemongrass, galangal, caraway, bergamot, basil, dill, lime, mint, brown rice, cabbage, cauliflower, napa, genus cassia leaf, soy, snake- head fish, catfish, short bodied mackerel fish, egg, coconut oil and milk, sweet potato, pumpkin, black bean, papaya, pineapple,

black grapes, pomelo, banana, butterfly pea, roselle, bael fruit, pandan leaf and cinnamon bark. The participants in this group were asked to refrain from drinking alcohol, consuming chemical ingredients, added sugar, salt, and transfat.

The control group had no change in food consumption. The control group was asked to maintain their regular lifestyle diet during the study period, which was approximately 1,500-1,700 kcal daily.

This study had three visits: baseline, week-6, and week-12 visits. At the baseline visit, data collection included demographic data and personal history by self-report questionnaire, vital signs, and physical examination by a physician. Anthropometric measurements included total body weight (kg), height (cm), percent body fat, muscle mass, and fat mass. DEXA scan (HOLOGIC Osteoporosis Assessment Discovery QDR Series) measuring the bone mineral density (T-score) was assessed. Blood specimens were drawn and collected after 12-hour overnight fasting at baseline and week-12 visits for HbA1C, lipid profiles, inflammatory markers including hsCRP and serum homocysteine. The marker hsCRP was also collected during the week-6 visit. Blood specimens for glycated hemoglobin (HbA1C) levels were tested using the turbidimetric inhibition immunoassay (TINIA) method. The lipid profile was tested by enzymatic method. For inflammatory markers, the hsCRP level was tested using a particle enhanced immunoturbidimetric assay, and the homocysteine level was tested using an enzymatic assay. Study participants were advised to adhere to study protocol during the study period and record their daily food intake, then assessed by a professional dietitian.

The primary endpoint was the comparison the change in inflammatory markers from baseline (hsCRP and homocysteine levels) between the two groups at different time points. The secondary endpoints were comparisons the changes in lipid profiles, HbA1C level, bone mineral density, and anthropometric measurements between the two groups.

2.2 Statistical analysis

Demographic data were presented by mean and standard deviations (SD) for continuous data and categorical data with frequency and percentage. An independent t-test and Wilcoxon ranked-sum test were used to analyze the differences in inflammation markers, blood pressure, HbA1C, lipid profiles, body mass index, waist circumference, percent body fat and bone density between the experimental group and the control group. Categorical data were compared using Pearson's chi-squared or Fisher's exact test. Data analysis was performed using Statistical Package for the Social Sciences (SPSS) version 23.0 for Windows. Statistical significance with a p-value of less than 0.05 was used.

3. Results

3.1 Clinical characteristics of study participants

Eighty participants were enrolled; Four of them were excluded due to pregnancy and taking medications. Seventy-six participants completed the study. The mean age (± SD) was 39.9±8.3 years, 11.8% of participants were male and 88.2% female. The average body weight was 73.3±15.4 kg, with no significant difference between the groups (p =0.917) (Table 1). There was no statistical difference between the overall average caloric intake throughout the 12-week duration of the study. The average, daily calorie intake of study participants in the nutrition intervention group was 1,686.4 kcal per day, while the maintain lifestyle group was 1,682.4 kcal per day with no statistical difference (p = 0.928).

3.2 Blood chemistry profiles

At baseline, blood chemistry profiles did not differ between the two groups except for significantly higher HDL levels in the ML group (p = 0.024). During the week-12 visit (endpoint), the nutrition intervention group had significantly greater reduction in diastolic blood pressure from the baseline (-5.42±9.7 mmHg) than the ML group (-0.13±8.6 mmHg, p=0.015). Furthermore, the NI group showed significantly greater reduction from baseline to week-12 visit in total cholesterol level, (-7.55±29.8 mg/dL, p = 0.019), triglyceride level (-36.5±66.9 mg/dL, p<0.001), HbA1C level (-0.85±2.0 mg%, p = 0.002) and TG/HDL ratio (-0.13± 0.32, p=0.001) compared to the ML group. However, LDL-cholesterol and HDL-cholesterol levels did not have a significant change (Table 1).

3.3 Inflammatory markers

Inflammatory markers hsCRP and homocysteine at baseline, six weeks (hsCRP only), and twelve weeks are presented in Table 2. Inflammatory markers at baseline visit did not differ between the two groups. After twelve weeks of study, the hsCRP level of NI group showed a statistically significant greater reduction for mean different change from baseline to week-12 visit than the ML group (-0.79±1.4 *vs.*+0.16 ± 2.2 mg/L, respectively, p=0.029) (Figure 1). Moreover, the NI group showed significantly greater homocysteine level reduction from the baseline to the week-12 visit than the ML group with a mean change of -0.34±2.35 *vs.*+1.87 ± 3.49 µmol/L, respectively (p=0.002). (Table 2).

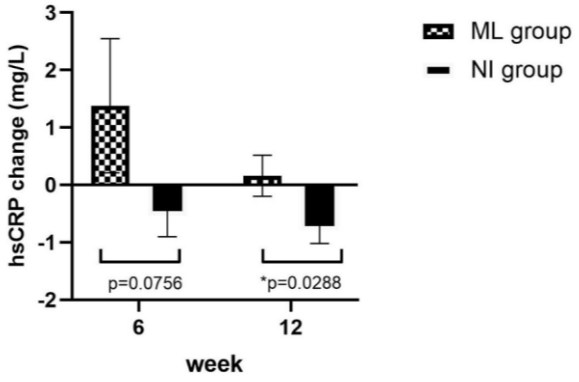

Figure 1. To compare hsCRP change from baseline between NI and ML group

3.4 Anthropometric measurement

Body weight, body mass index, waist-hip circumference, percent body fat, fat mass, lean mass and bone mineral density at baseline, and twelve weeks are presented in

Table 1. Clinical characteristics and blood chemistry profiles

Variables	ML group (Control) (n =38)		NI group (n=38)		*P**	*P***
	Baseline	12-week	Baseline	12-week		
Age, mean (SD), years	38.1 (9.5)	-	41.7 (6.6)	-	0.159[a]	-
min-max (years)	22-53	-	24-54	-		
Gender						
-Male, n (%)	2 (5.3)	-	7 (18.4)	-	0.076[c]	-
-Female, n (%)	36 (94.7)	-	31 (81.6)	-	-	
SBP, mean (SD), mmHg	122.1 (13.7)	117.9 (12.7)	125.9 (13.8)	116.4 (13.0)	0.233[b]	0.607[b]
SBP change, mean (SD), mmHg	-	-4.21 (11.9)	-	-9.53 (12.0)	-	0.057[b]
DBP, mean (SD), mmHg	75.8 (9.5)	77.7 (9.6)	77.2 (9.9)	71.7 (10.2)	0.556[b]	0.085[b]
DBP change, mean (SD), mmHg	-	-0.13 (8.6)	-	-5.42 (9.7)	-	0.015[b]
TC, mean (SD), mg/dL	203.3 (35.8)	210.5 (32.8)	181.8 (34.9)	174.3 (30.4)	0.080[b]	< 0.001[b]
TC change, mean (SD), mg/dL	-	7.23 (27.2)	-	-7.55 (29.8)	-	0.019[b]
TG, mean (SD), mg/dL	123.3 (83.2)	145.8 (117.8)	124.7 (69.7)	88.2 (40.5)	0.716[a]	< 0.001[a]
TG change, mean (SD), mg/dL	-	22.5 (82.7)	-	-36.5 (66.9)	-	< 0.001[b]
LDL, mean (SD), mg/dL	142.2 (30.6)	141.7 (29.9)	128.4 (31.8)	120.5 (27.6)	0.058[b]	0.002[b]
LDL change, mean (SD), mg/dL	-	-2.16 (6.8)	-	-2.42 (6.7)	-	0.880[b]
HDL, mean (SD), mg/dL	54.4 (11.6)	52.2 (11.4)	48.3 (11.6)	45.8 (10.4)	0.024[b]	0.013[b]
HDL change, mean (SD), mg/dL	-	-0.47 (20.5)	-	-7.95 (22.7)	-	0.147[b]
TG/HDL ratio	2.54 (2.39)	3.35 (4.22)	2.96 (2.38)	2.11 (1.28)	0.306[a]	0.073[a]
TG/HDL ratio change	-	0.05 (0.25)	-	-0.13 (0.32)	-	0.001[b]
HbA1C, mean (SD), mg%	5.57 (1.37)	5.92 (1.45)	5.43 (0.45)	5.30 (0.32)	0.665[a]	0.171[a]
HbA1C change, mg%	-	0.81 (3.2)	-	-0.85 (2.0)	-	0.002[b]

[a] Footnote 1: Non-normal distributed data using the Wilcoxon rank-sum test
[b] Footnote 2: Normal distributed data using Independent student t-test
[c] Footnote 3: Categorical data using Pearson's chi-squared or Fisher's exact test
[*] Footnote 4: P^*, Comparison of the means between the 2 groups at baseline visit
[**] Footnote 5: P^{**}, Comparison of the means between the 2 groups at the 12-week visit
Abbreviation: NI group = Nutrition Intervention group, ML = Maintain Lifestyle group, SD = standard deviation, kg = kilogram, SBP = systolic blood pressure, DBP = diastolic blood pressure, TC = Total cholesterol, TG = Triglyceride, LDL = Low density lipoprotein-cholesterol, HDL = High density lipoprotein-cholesterol, HbA1C = Glycated hemoglobin

Table 2. Inflammatory markers

Inflammatory markers	ML group (control) (n = 38)			NI group (n=38)			*P**	*P***
Mean (SD)	Baseline	6-week	12-week	Baseline	6-week	12-week		
hsCRP, mg/L	3.56 (2.3)	4.94 (7.4)	3.71 (3.2)	3.49 (3.2)	2.96 (2.8)	2.71 (2.6)	0.253[a]	0.077[a]
hsCRP diff. change, mg/L	-	1.38 (7.2)	0.16 (2.2)	-	-0.53 (2.3)	-0.79 (1.4)	0.0756	0.0288[a]
% hsCRP change, %	-	49.9 (209.8)	7.2 (73.1)	-	15.8 (191.9)	-14.8 (37.7)	-	0.078[a]
Homocysteine level, µmol/L	13.6 (2.5)	-	15.5 (3.5)	14.1 (3.1)	-	13.8 (2.8)	0.292[a]	0.018[b]
Homocysteine diff. change, µmol/L	-	-	1.87 (3.49)	-	-	-0.34 (2.35)	-	0.002[a]
% Homocysteine change, %	-	-	15.7 (27.7)	-	-	-0.29 (18.6)	-	0.010[a]

[a] Footnote 1: Non-normal distributed data using the Wilcoxon rank-sum test
[b] Footnote 2: Normal distributed data using Independent student t-test
Abbreviation: NI group = Nutrition Intervention group, ML = Maintain Lifestyle group, hsCRP = High Sensitivity C-Reactive Protein, SD = Standard Deviation, Diff. change = different change from the baseline
[*] Footnote 4: P^*, Comparison of the means between the 2 groups at baseline visit
[**] Footnote 5: P^{**}, Comparison of the means between the 2 groups at week-12 visit

Table 3. The variables at the baseline did not differ significantly between the two groups. After twelve weeks of study, the NI group demonstrated a significantly greater decrease from baseline in body weight of -5.14±4.6 kg ($p<0.001$), and in BMI of -1.96±1.7 kg/m^2 ($p<0.001$) compared with the ML group. Comparing between those with WHR > 0.95 male, > 0.85 female, or truncal obesity, the NI group had a statistically significant lower proportion (34.2% *vs*. 57.9%, respectively, ($p=0.038$) than the ML group of 12-weeks. The mean change from the baseline of percent body fat (-2.06 ± 2.0 %), fat mass (-3.2 ± 2.4 kg) and lean mass (-1.55±1.6 kg) in the NI group was significantly greater ($p <0.001$) than in the ML group. The mean change from baseline of bone mineral density, T-score of the NI group was slightly higher but not significantly different from compared to the ML group ($p=0.073$).

Table 3. Anthropometric measurement

Anthropometric measurement	ML group (Control) (n =38)		NI group (n=38)		*P**	*P***
	Baseline	12-week	Baseline	12-week		
Body weight, mean (SD), kg	73.0 (16.0)	74.0 (16.6)	73.3 (15.1)	68.1 (14.3)	0.917[a]	0.124[a]
Body weight change, mean (SD), kg	-	0.98 (4.3)	-	-5.14 (4.6)	-	<0.001[a]
% Body weight change, mean (SD), %	-	0.34 (1.6)	-	-6.86 (5.8)	-	<0.001[a]
BMI, mean (SD), kg/m²	28.8 (5.4)	29.1 (5.5)	28.0 (4.4)	25.0 (4.1)	0.561[a]	0.012[a]
BMI change, mean (SD), kg/m²	-	0.34 (1.6)	-	-1.96 (1.7)	-	<0.001[a]
BMI > 25 kg/m², n (%)	24 (63.2)	15 (39.5)	24 (63.2)	14 (36.8)	1.000[c]	0.813[c]
BMI > 30 kg/m², n (%)	12 (31.6)	16 (42.1)	10 (26.3)	13 (34.2)	0.613[c]	0.479[c]
WHR, mean (SD)	0.86 (0.06)	0.84 (0.61)	0.87 (0.08)	0.82 (0.05)	0.430[b]	0.316[b]
WHR change, mean (SD)	-	-0.02 (0.05)	-	-0.05 (0.05)	-	0.042[b]
WHR > 0.95 male, > 0.85 female, n (%)	22 (57.9)	22 (57.9)	20 (52.6)	13 (34.2)	0.645[c]	0.038[c]
Percent Body Fat, mean (SD), %	42.3 (4.65)	41.9 (4.55)	39.5 (5.12)	37.4 (5.41)	0.015[b]	0.001[a]
Percent Body Fat change, mean (SD), %	-	-0.41 (1.2)	-	-2.06 (2.0)	-	<0.001[a]
Fat Mass, mean (SD), kg	31.3 (9.5)	31.2 (9.6)	28.6 (6.8)	25.4 (6.8)	0.339[a]	0.006[a]
Fat Mass change, mean (SD), kg	-	-0.12 (1.7)	-	-3.20 (2.4)	-	<0.001[a]
Lean Mass, mean (SD), kg	39.6 (4.16)	40.1 (7.07)	41.6 (0.96)	40.1 (9.23)	0.400[a]	0.611[a]
Lean Mass change, mean (SD), kg	-	0.52 (1.6)	-	-1.55 (1.6)	-	<0.001[a]
BMD / T- score, mean (SD)	0.68 (1.02)	0.68 (0.99)	0.51 (0.94)	0.59 (0.91)	0.450[b]	0.675[b]
BMD / T-score change, mean (SD)	-	0.005 (0.16)	-	0.084 (0.21)	-	0.073[b]

[a] Footnote 1: Non-normal distributed data using the Wilcoxon rank-sum test
[b] Footnote 2: Normal distributed data using Independent student t-test
[c] Footnote 3: Categorical data using Pearson's Chi-squared or Fisher's exact test
[*] Footnote 4: P^*, Comparison of the means between the 2 groups at baseline visit
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Abbreviation: NI group = Nutrition Intervention group, ML = Maintain Lifestyle group, SD = Standard Deviation, kg = kilogram, BMI = Body Mass Index, WHR = Waist Hip Ratio, BMD = Body Mineral Density

4. Discussion

The findings of the study indicated for the first time in a clinical study that a plant-based Thai diet improves inflammatory markers hsCRP and homocysteine. It also improves blood pressure, total cholesterol, triglycerides, LDL cholesterol, TG/HDL ratio, HbA1C, body weight, body mass index, percent body fat, and fat mass. Plant-based Thai diets can also be an anti-hypertensive diet. Even though bone mineral density did not improve to a significant level, and it had a tendency to improve. The results showed that the twelve-week intervention of plant-based Thai diets improved health in many ways, especially reducing the inflammatory markers and body fat. Unfortunately, the lean mass was also affected, which requires further investigation into the cause and how to prevent it.

The data showed that plant-based Thai diets could improve blood pressure. The plant-based Thai diet in this study was rich in antihypertensive herbs such as garlic, onion, cilantro, roselle flower, and ginger, which were proven to have antihypertensive benefits (Al Disi, Anwar, & Eid, 2015). The pharmacological mechanism of action of herbs and plants is medicine for the prevention and cure of cardiovascular diseases. They improve blood pressure by affecting reactive oxygen species, vascular smooth muscle cell phenotype, endothelium, platelet activation, pro-inflammatory signalling, and gene expression (Al Disi *et al.*, 2015). More clinical research is needed to prove the health benefit of herbs used for a century without dangerous side effects such as black cumin, Chinese sage, coriander, garlic, ginger, ginseng, and tea.

Results from this study show that consumption plant-based Thai diets significantly improves or has anti-inflammatory effects by demonstrating greater the mean change reduction of hsCRP level and homocysteine level than the controls at the endpoint visit. This impact could be due to the antioxidant and anti-inflammatory properties of anti-inflammatory ingredients in plant-based Thai diets. Antioxidative substances such as phenolic acid, flavonoid, vitamin A, beta-carotene and vitamin C were predominantly found in Plant-based Thai diets (Tharasena & Lawan, 2014). Previous studies suggested that obesity causes chronic inflammation, and a plant-based diet can improve weight loss and decrease inflammation (Eichelmann *et al.*, 2016). Therefore, consuming plant-based Thai diets is beneficial to overall health as it not only has anti-inflammatory property, but also assists in weight loss.

In this study, the significant decrease from the baseline to the week-12 visit of serum total cholesterol level, triglyceride level, HbA1C, and TG/HDL ratio indicate a plant-based Thai diet can help to a maintain a healthy lifestyle. These findings correspond to the study conducted by Yokoyama *et al.* which found that vegetarian diets were associated with a decrease in serum lipid profiles, including total cholesterol, LDL-C, and HDL-C level (Yokoyama, Levin, & Barnard, 2017). Plant-based Thai diets effectively improved lipid profile and glucose levels, as found in this study. The improvement of lipid profiles may be the consumption of a fiber-rich diet and limited meat protein. Plant-based Thai diets are considered like a semi-vegetarian (flexitarian) diet, which includes small amounts of fish and poultry (Pawlak, 2017). It is not as strict as a vegetarian diet, which excludes all meat and animal products (Pawlak, 2017). This study also indicated that a plant-based diet could reduce serum triglyceride levels in the NI group. The reason why plant-based Thai diets affect serum triglyceride levels is that they contains low glycemic components, and subjects were

not allowed to consume alcohol or unhealthy fat such as transfat. A previous study confirmed the association between high serum triglyceride and impaired fasting plasma glucose (Daboul, 2011). Another finding was the plant-based Thai diets could increase HDL-C level, this phenomenon can be explained by high consumption of coconut oil (Muller, Lindman, Brantsaeter, & Pedersen, 2003), purple colored plants (Zhu *et al.*, 2013) and fatty fish (Erkkila *et al.*, 2014) and its avoidance of artificial trans fats (Brouwer, Wanders, & Katan, 2010).

Plant-based Thai diets in our study mainly contain daily berry rice, which improves HbA1C levels. Our results can be confirmed by the findings of the previous study published by Lee *et al.*, which determined the impact of a brown rice-based vegan diet on glycemic control among 46 Korean patients. The results of the study showed a significant reduction in HbA1C level at 12 weeks duration. In addition to the improvement of HbA1C level, a plant-based Thai diets study found a statistically significant reduction of total body weight ($p<0.001$) and body mass index ($p<0.001$) compared to the control group (Lee *et al.*, 2016). These findings support the evidences from previous studies which sought to determine the clinical effects of a vegetarian or plant-based diet on weight reduction (Huang *et al.*, 2016; Turner-McGrievy, Davidson, Wingard, Wilcox, & Frongillo, 2015).

In addition, plant-based Thai diets showed a statistically significant decrease ($p<0.001$) in waist-hip ratio, percent body fat, and fat mass compared to the control group. Our study confirms that consumption of plant-based Thai diets is practical and useful as a method for controlling body weight and body fat in overweight and obese individuals. Despite the reduced lean mass due to significant weight loss, this phenomenon may commonly occur after body weight reduction as the previous study reported (Willoughby, Hewlings, & Kalman, 2018). We hypothesized that lean mass reduction may be short-term, transiently decreased lean mass phenomenon occurring after losing total body weight and may improve by taking chromium picolinate supplements, weight training exercise, and eating the appropriate amount of protein, fat, and carbohydrate (Willoughby *et al.*, 2018).

The average change of bone mineral density suggested a trend to improve ($p=0.073$) in the plant-based diet group compared to the controls. The explanation for this improvement is that Thai cuisine is rich in calcium, especially from small shrimps and fishes that have edible shells or bone. Many Thai leafy greens are vibrant with bioavailable calcium. Participants in this 12-week study consumed calcium-rich diets from dried shrimp and shrimp paste in yellow curry paste, which was served four times a week. High calcium tempeh (43 mg per serving) was served four times a week. Calcium-rich leafy green vegetables such as wild betel leaf (calcium 601-841 mg per 100 grams), Chinese kale and Indian mulberry leaf were regularly served. In addition, a sweet potato, that has calcium more than 50 mg per serving was served once a week.

5. Conclusions

The reduction of inflammatory markers, hsCRP and homocysteine levels, the improvement of blood lipid-lowering and weight control effects were demonstrated by the consumption of plant-based Thai diets. Plant-based Thai diets may reduce the potential risk of chronic inflammatory diseases. Further studies are needed to assess the benefits of plant-based Thai diets in specific populations such as the elderly, diabetes, hypertension, or other chronic inflammatory diseases. Serum novel biomarkers such as serum adiponectin, interleukin-10 levels, homeostasis model assessment of insulin resistance (HOMA-IR) and tumor necrosis factor-α (TNF-α) should be further tested for inflammatory marker in this specific population.

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