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The effects of Dyglomera® (*Dichrostachys glomerata* extract) on body fat percentage and body weight: a randomized, double-blind, placebo-controlled clinical trial

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ABSTRACT

Introduction: Previous studies have shown the beneficial effects of Dyglomera®, a hydroethanolic extract of *Dichrostachys glomerata*, on inflammation as well as parameters linked to metabolic syndrome. Its effect on body fat was however not verified. The present study was therefore carried out to evaluate the anti-obesity effect of the Dyglomera®, on overweight and obese subjects.

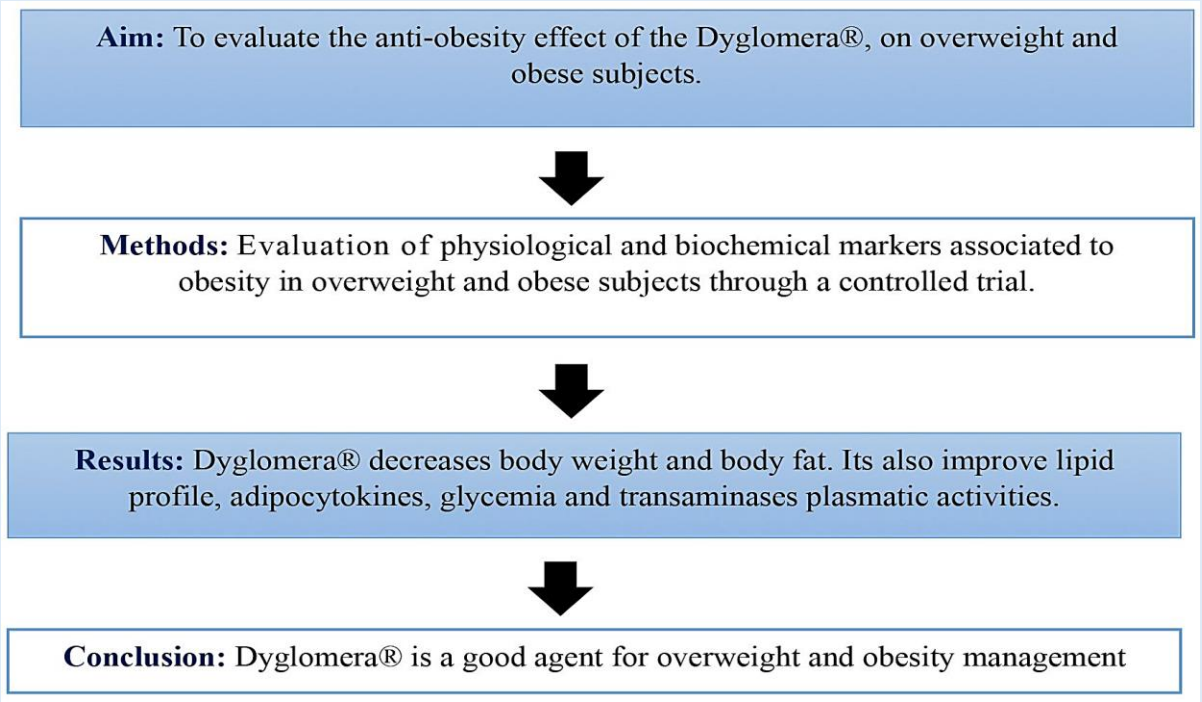
Methods: This 12-week randomized, double-blind placebo-controlled trial had percentage body fat measured by dual-energy X-ray absorptiometry, body weight and body mass index set as efficacy endpoints. On the other hand, key biochemical parameters were measured as secondary endpoints. The values of these parameters at T_{12} compared to T_0 for the placebo and Dyglomera® groups were used as a measure of the efficacy.

Results: Subjects treated with Dyglomera® for 12 weeks showed significant differences, with 6.73 kg ($p<0.05$) decrease in the body weight and 22.85% ($p<0.05$) reduction in the percentage body fat. In addition, the markers of lipid profile, adipocytokines, glycemia and transaminases plasmatic activities were also improved by the intake of Dyglomera®.

Conclusions: This study shows that Dyglomera® effectively decreases the body weight in obese subjects after 12 weeks of treatment, and it was accompanied by a reduction in the body fat and related disorders. Dyglomera®is a good agent for overweight and obesity management.

Keywords: *Dichrostachys glomerata*, Dyglomera®, body fat percentage, body weight, clinical trials.

Graphical Abstract of main activities from sample collection to analysis.



INTRODUCTION

Obesity increases the risk of various chronic diseases, such as high blood pressure, diabetes, and cardiovascular disease, and shortens lifespan [1,2,3]. Obesity is a public health problem with a high prevalence [4]. The WHO classified obesity as a chronic disease in 1995.It significantly contributes to the global burden of chronic diseases [5].

Obesity is known as a complex syndrome caused by various environmental factors, including genetic factors and lifestyle factors such as stress, lack of physical activity, excessive drinking and smoking. However, the cause and mechanisms of obesity have not been clearly elucidated [6,7,8,9].

In order to improve obesity, in addition to surgical treatment, exercise to reduce body weight and fat accumulation, dietary control such as caloric restriction, and drug treatment for weight loss have been suggested, but these methods do not last long and cause various side effects [10,11,12]. For this reason, the interest in health functional foods, which are natural products or compounds derived from natural products that are considered safer, is increasing [13,14].

Phenolic compounds, one of the secondary

metabolites of plant components, are widely distributed in plants. They are classified into phenolic acid, coumarin, flavonoid, and tannin [15]. These polyphenols are abundant in beverages, fruits and spices derived from plants such as cacao, grapes, tea, berries, onion, and herbs [16,17,18,19].

Dichrostachys glomerata (synonym: *Dichrostachys cinerea*) is a deciduous tree found in India, Africa, and other tropical countries [20,21,22]. The dried fruits of *D. glomerata* (DG) are commonly used as a spice in the Cameroonian traditional soup "Nah-poh" [23]. The bark of DG is used in folk remedies to treat dysentery, headache, and syphilis, and the roots and leaves are used as traditional medicines to treat epilepsy [20,21,24]. DG contains various phytochemical components such as sterols, alkaloids, terpenoids, polyphenols, and glycosides [25,26].

The results of *in-vitro* and *in-vivo* tests showed that this plant had antiviral, anti-infectious, anti-inflammatory and analgesic effects, inhibitory activity on low-density lipoproteins (LDL) oxidation, and improvement of obesity and type 2 diabetes [27,28,29,30,31,32,33]. In addition, the results of our research team's clinical trial on patients with metabolic diseases showed that the intake of DG extract greatly contributed to the improvement of antioxidant activity in the body and the improvement of cardiovascular risk factors [34,35]. In the previous clinical study to evaluate the efficacy of DG, it was confirmed that weight loss and fatty acid-related factors were decreased, however the change in body fat was not measured [34].

Body fat percentage has higher sensitivity and specificity than classic anthropometric parameters (such as waist circumference, body mass index (BMI), waist-to-height ratio), so it can be used as a tool to measure excessive adiposity [37]. It has also been suggested that body fat percentage is a better indicator of other adiposity-related comorbidities, such as coronary heart disease risk and diabetes, than waist circumference and BMI [37,38].

Dual-energy X-ray absorptiometry (DEXA) is a widely used method for body composition analysis, which can detect obesity and accurately measure total and regional proportions of fat [39,40,41].

In order to evaluate the anti-obesity effect of the DG extract (Dyglomera®), which shows metabolic disease improvement activity, this clinical study was conducted on overweight and obese subjects. For this study, body fat percentage, body weight, and BMI were set as efficacy endpoints for obese people aged 19 to 65 years. The effects of Dyglomera® on each endpoint were evaluated by comparing the differences of before and after.

For accurate interpretation of the effects of daily oral administration of 400 mg of Dyglomera® in obese subjects, this clinical study evaluated the effect of Dyglomera® on body fat percentage with DEXA.

METHODOLOGY:

Test Material: Dyglomera®, a hydroethanolic extract of DG, was supplied by Gateway Health Alliances, Fairfield, California, USA. They were supplied as 400 mg capsules. Identical-looking placebo capsules were also manufactured containing 400 mg of dextrin.

Study population and intervention: The study was a double-blind, placebo-controlled trial lasting 12 weeks. Volunteers were recruited at Max Super Specialty Hospital, New Delhi, and 120 subjects were randomly assigned to the clinical study. The participants included healthy males and non-pregnant/non-lactating females aged 19–65 years, with a BMI between 25.0-34.9 kg/m^2.

Participants were examined to ensure they were eligible for inclusion in the study. Participants were randomly divided into two groups and instructed to take 400 mg of either Dyglomera® or a placebo once a day before lunch or dinner for the duration of the study. They

were asked to report any lapses in taking the pills. The size and shape of the capsules were prepared so that neither the researcher nor the participant could distinguish the capsules. Participants were encouraged to maintain their previous lifestyle and dietary habits throughout the study.

Exclusion criteria: The exclusion criteria for the study were as follows: (1) patients not available for the study period; (2) patients aged below 19 years and greater than 65 years; (3) morbid obesity (BMI > 34.9 kg/m2); (4) diabetes mellitus requiring daily insulin management; (5) pregnancy/lactation; (6) active infection; (7) systemic disease such as HIV/AIDS, active hepatitis or clinical signs of active malignancy within the past 5 years; (8) those taking any other medications or any natural health product within 1 month prior to the screening visit that affects weight; (9) those judged by the investigator to be ineligible for any other reason.

Approval and informed consent: The study was conducted according to the Guideline for Good Clinical Practice by the International Conference on Harmonization (ICH GCP) and the Helsinki Declaration. The study was conducted under the review and approval of the Independent Review Board (IRB) of Max Super Specialty Hospital for the protocol and informed consent form before implementation of the study. The investigator obtained written informed consent to participate after explaining the nature, scope, and expected results of the study in advance to the subjects participating in the human study.

Efficacy outcome measurements: Various anthropometric parameters were measured at baseline and at biweekly follow-up visits for the 12 weeks of treatment. Height was measured at Visit 1 and body weight and body mass index (BMI, kg/m^2) were measured at every visit. At Visits 1, 2, 3, 4, and 5, waist circumference and hip circumference were measured. For measurement of waist and hip circumference, the circumference of two parts of the body (waist, hip) was measured with an anthropometric tape while the subject stood on a flat floor, and the waist-hip ratio was also measured. Body fat percentage (%), body fat mass (g), and lean body mass (g) were measured by using Dual Energy X-ray Absorptiometry (DEXA) at C-reactive protein (CRP), alanine transaminase (ALT), aspartate transaminase (AST), fasting blood glucose, leptin, and adiponectin levels were measured by blood chemical tests. For the examination of the lipid metabolism index, total cholesterol, HDL-cholesterol, and LDL-cholesterol levels were measured.

Safety outcome measurements: The safety assessments comprised electrocardiography, vital sign measurement (blood pressure), and clinical laboratory tests (ALP, total bilirubin, total protein, albumin, creatinine, total bilirubin, Na, and Ca).

Statistical analysis: The data were summarized (mean and standard error) for Week 0 (baseline), Week 4, Week 8, and Week 12 (final), and the intra-group variation and the data were analyzed using SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA). The results were compared within groups (Dyglomera® and Placebo) and between groups using student t-test and ANOVA respectively. The unpaired student t-test was used to compare data between groups (Dyglomera® and Placebo) and the paired Student's t-test for comparison in intragroup data (at the start and end values). The significance was noted at $p < 0.05$.

The degree of change before and after intake of body fat percentage measured by DEXA, the primary efficacy evaluation endpoint, was analyzed using the paired t-test. For the degree of change between the

groups at each time point, the ANOVA and two-sample t-test were performed to evaluate whether there was a statistically significant difference.

The degree of changes in weight, waist circumference, hip circumference, waist to hip ratio, body mass index, body fat mass by DEXA, fasting blood glucose, ALT, AST, blood lipids (total cholesterol, HDL-cholesterol, LDL-cholesterol), CRP, adiponectin, and leptin, which are the secondary efficacy endpoints, were analyzed using the Paired t-test.

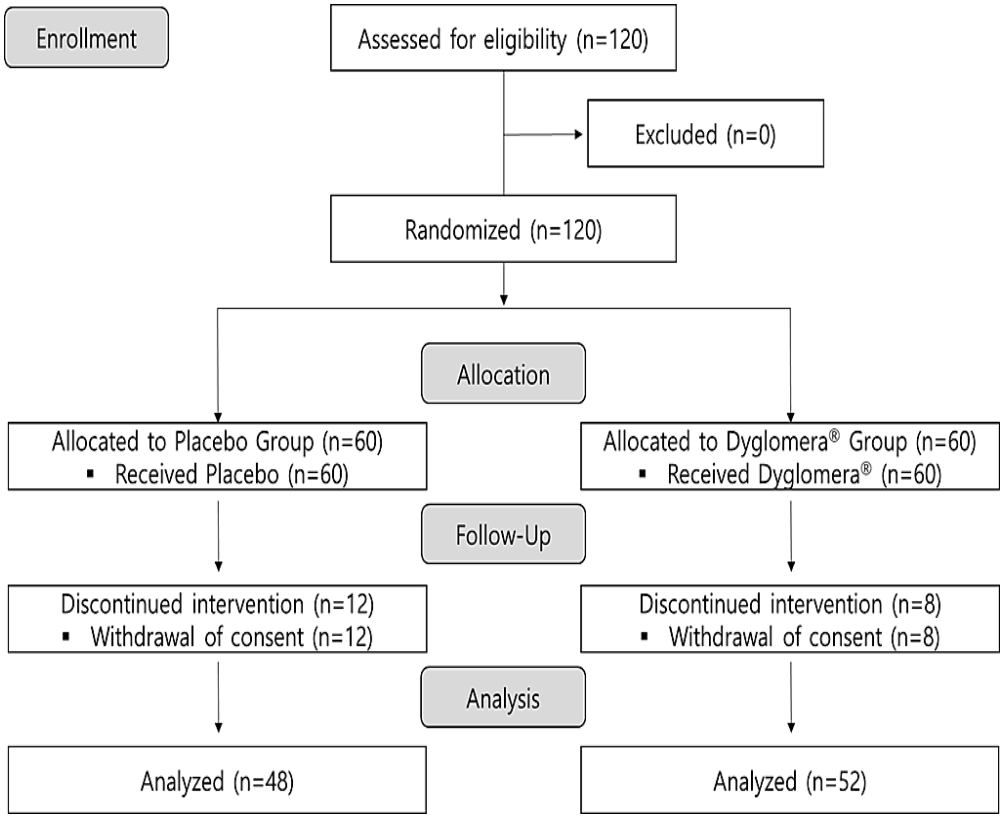
Safety evaluation was largely based on abnormalities of clinically measured adverse events, clinical laboratory tests, and vital signs. The proportion of subjects who had adverse events between each group was calculated and comparatively analyzed using the Chi-square test or Fisher's exact test. The two-sample t-test was used to analyze inter-group comparison. Change values were calculated by comparing the clinical laboratory test results before intake (Screening visit) and after intake (Closing visit).

Selection of subject population to be included in analysis: In the safety set, as subjects who had taken the investigational product at least once after being randomized to the human study, 60 subjects in the test group and 60 subjects in the placebo group were included in the analysis.

The FA set consists of the subject population who had taken the investigational product at least once and then conducted the efficacy evaluation at least once, and who did not violate the inclusion/exclusion criteria. For the PP set, subjects who completed the clinical study and had no significant violations affecting the results of the study were included in the FA set analysis. A total of 100 subjects (52 subjects in the test group, 48 subjects in the control group) were included in the PP set.

Flow Diagram: The detailed treatment procedure is outlined in the flowchart in Figure 1.

Figure 1. Flow diagram of study participants. Dyglomera®, 400 mg of Dichrostachys glomerata



RESULTS:

Demographic Baseline characteristics: A total of 100 individuals (52 in the Dyglomera® treatment group and 48 in the placebo group) out of 120 initial participants completed the study (20 participants dropped out of the study). In the result of the investigation for the demographic information and baseline characteristics of subjects, the test group included 26 males (50%) and 26 females (50%), and the control group included 23 males (47.91%) and 25 females (52.08%). The average age was 40.91±10.14 years in the test group and 41.78±9.52 years in the control group. There were no statistically significant differences between groups at baseline for all the parameters that were measured

Effect of Dyglomera® on athropometric parameters:

Body fat percentage: The change in body fat percentage by DEXA measured at Weeks 0 and 12 of intake is shown in Table 1. In the analysis of the change in body fat percentage, body fat percentage after 12 weeks of intake decreased by 22.85% in the Dyglomera® group, and remained stable in the placebo group (0.46% variation), showing a statistically significant difference ($p<0.05$) between the intake groups (Table 1).

Table 1. Change in body fat percentage by DEXA.

Sample	T0 (%)	T4 (%)	T8 (%)	T12 (%)	% change over 12 weeks
Placebo	19.35±2.02	19.56±1.59	19.38±1.90	19.44±1.74	0.46
Dyglomera®	19.74±2.34	18.68±2.14 *	17.20±1.98#, *	15.23±1.80#, *	-22.85 *

#p<0.05: comparison between the start value (T0) within the in the same group, intra-group analysis.

** p<0.05: comparison between Dyglomera® and Placebo in the same column; inter-group analysis*

Body weight: The change in body fat percentage by DEXA measured at Weeks 0 and 12 of intake is shown in Table 2. In the analysis of the change in weight after 12 weeks of intake decreased by 6.73 kg in the Dyglomera® group, and by 0.08 kg in the placebo group, showing a statistically significant difference ($p<0.05$) between the intake groups.

Waist circumference, Hip circumference, Waist to hip ratio: The changes in waist circumference, hip circumference, and waist to hip ratio measured at Weeks 0, 4, 8, and 12 of intake are shown in Table 3. The waist circumference after 12 weeks of intake decreased by 6.06% in the Dyglomera® group, and by 1.45% in the placebo group, showing a statistically significant difference ($p<0.05$) between the intake groups. Hip circumference after 12 weeks of intake decreased by 8.39% in the Dyglomera® group, and by 0.34% in the placebo group, with a statistically significant difference between the intake groups. Waist to hip ratio after 12 weeks of intake increased by 3.00% in the Dyglomera® group, and decreased by 1.00% in the placebo group. This increase was an indication of the fact that the reduction was more prominent in the hip compared to the waist.

Body Mass Index (BMI): Table 4 shows the results of analysis for the changes in BMI at Weeks 0, 4, 8 and 12 of intake. The BMI after 12 weeks of intake decreased by 7.79% in the Dyglomera® group, and by 0.07% in the placebo group, showing a statistically significant difference ($p<0.05$) between the intake groups.

Blood markers: The results of analysis for the blood markers (Total cholesterol, HDL-cholesterol, LDL-cholesterol, CRP, Leptin, Adiponectin, Insulin, Fasting

blood glucose, ALT, and AST) measured at Weeks 0, 4, 8, and 12 of intake are shown in Table 5.

Table 2. Changes in body weight by visit

Sample	T0 (kg)	T4 (kg)	T8 (kg)	T12 (kg)	% change over 12 weeks
Placebo	86.57±6.45	86.46±6.27	86.53 ± 7.79	86.49±2.78	-0.09
Dyglomera®	86.39±7.04	86.27±7.14	82.89±6.58 *	79.66±7.24#, *	-7.79 *

#p<0.05: comparison between the start value (T0) within the in the same group, intra-group analysis.
** p<0.05: comparison between Dyglomera® and Placebo in the same column; inter-group analysis.*

Table 3. Changes in waist circumference, hip circumference, and waist-to-hip ratio

Sample	Groups	T0	T4	T8	T12	% change over 12 weeks
Waist Circumference (cm)	Placebo	102.81 ±2.05	101.52 ± 2.06	100.40 ±2.05	101.32 ± 2.06	-1.45
	Dyglomera®	102.98 ±2.80	100.14 ±1.31*	99.24 ±1.31 *	96.74 ±1.31#, *	-6.06 *
Hip circumference (cm)	Placebo	103.33 ±5.89	103.13 ±5.88	102.37 ±5.89	102.99 ±5.93	-0.34
	Dyglomera®	103.03 ±5.03	99.09 ±5.78*	97.29 ±5.78 *	94.39 ±5.77#, *	-8.39 *

#p<0.05: comparison between the start value (T0) within the in the same group, intra-group analysis.
** p<0.05: comparison between Dyglomera® and Placebo in the same column; inter-group analysis.*

Table 4. Changes in BMI by visit

Groups	T0 (kg/m²)	T4 (kg/m²))	T8 (kg/m²)	T12 (kg/m²)	% change over 12 weeks
Placebo	30.28±1.74	30.24±1.86	30.27±1.91	30.26±1.88	-0.07
Dyglomera®	30.43±1.96	30.38±1.88	29.19±2.19 *	28.06±2.13#, *	-7.79 *

#p<0.05: comparison between the start value (T0) within the same group, intra-group analysis.
** p<0.05: comparison between Dyglomera® and Placebo in the same column; inter-group analysis.*

Table 5. Changes in blood markers

	Groups	T0	T4	T8	T12	% change over 12 weeks
HDL-cholesterol (mg/dL)	Placebo	41.96 ±6.19	42.58 + 5.77	43.20 ±5.94	40.10 ±4.65	-4.43
	Dyglomera®	43.12 ±5.11	43.98 ±4.42	46.12 ±3.60 *	49.31 ±4.01#, *	+14.36 *
LDL-cholesterol (mg/dL)	Placebo	132.90 ±5.68	132.33 ±5.17	131.71 ±5.15	132.77 ±4.47	-0.10
	Dyglomera®	131.77 ±6.27	125.79 ±5.33 *	121.79 ±5.05 *	119.60 ±6.04#, *	-9.24 *
Total-cholesterol	Placebo	213.83 ±7.47	214.46 ±6.30	213.96 ±6.22	212.77 ±5.88	-0.50

	Groups	T0	T4	T8	T12	% change over 12 weeks
(mg/dL)	Dyglomera®	213.54 ±10.70	193.21 ±7.04 *	186.31 ±6.11 *	177.52 ±7.07#, *	-16.87 *
CRP (mg/mL)	Placebo	9.78 ±1.53	9.73 ±1.54	9.50 ±1.46	9.50 ±1.47	-2.86
	Dyglomera®	8.75 ±0.75	8.67 ±0.80 *	8.21 ±0.73 *	7.95 ±0.73#, *	-8.30 *
Leptin (ng/dL)	Placebo	12.41 ±1.96	12.38 ±1.97	12.37 ±1.94	12.37 ±1.96	-0.32
	Dyglomera®	12.48 ±1.46	12.68 ±1.46	11.18 ±1.46 *	11.08 ±1.45#, *	-11.22 *
Adiponectin (µg/dL)	Placebo	9.41 ± 2.06	9.42 ±1.85	9.82 ±1.83	9.92 ±1.88	+5.42
	Dyglomera®	9.34 ±0.98	9.49 ±0.96	9.84 ±0.90	10.08 ±0.89	+7.92 *
Insulin (IU/L)	Placebo	16.92 ±1.48	16.86 ±1.66	16.90 ±1.18	16.93 ±1.69	+0.06
	Dyglomera®	16.71 ±1.71	16.66 ±1.37	16.25 ±1.15	15.97 ±1.43	-4.37 *
Fasting blood glucose (nmol/L)	Placebo	4.98 ±0.43	4.95 ±0.46	4.94 ±0.43	4.94 ±0.44	-0.80
	Dyglomera®	5.07 ±0.39	5.05 ±0.39	4.99 ±0.43	4.89 ±0.43	-3.55 *
ALT (IU/L)	Placebo	33.78 ±1.53	32.53 ±1.54	35.40 ±1.46	37.50 ±1.47	+11.01
	Dyglomera®	33.71 ±3.14	30.54 ±3.21 *	26.83 ±1.06 *	22.71 ±3.07#, *	-32.63 *
AST (IU/L)	Placebo	33.48 ±3.20	30.23 ±1.54	34.43 ±3.28	35.68 ±3.23	+6.57
	Dyglomera®	33.47 ±5.16	30.49 ±5.84	28.50 ±3.38 *	24.65 ±5.61#, *	-26.35 *

#p<0.05: comparison between the start value (T0) within the in the same group, intra-group analysis.
** p<0.05: comparison between Dyglomera® and Placebo in the same column; inter-group analysis.*

Leptin and Adiponectin: Leptin after 12 weeks of intake decreased by 11.22% in the Dyglomera® group and by 0.32% in the placebo group. Adiponectin after 12 weeks on intake increased by 7.92% in the Dyglomera® group and by 5.42% in the placebo group, with no statistical difference between the two groups (p>0.05).

Insulin: After 12 weeks of intake, insulin decreased by 0.74 IU/L in the Dyglomera® group and increased by 0.01 IU/L in the placebo group corresponding to a variation percentage of -4.37% and 0.06% respectively.

Fasting blood glucose: The fasting blood glucose after 12 weeks of intake decreased by 3.55% in the Dyglomera® group and by 0.80% in the placebo group.

ALT and AST: After 12 weeks of intake, ALT decreased by 11.00 IU/L in the Dyglomera® group and increased by 3.72 IU/L in the placebo group corresponding to a variation percentage of -32.63% and +11.01% respectively. AST after 12 weeks on intake decreased by 8.82 IU/L in the Dyglomera® and increased by 2.2 IU/L in the placebo group, corresponding to a variation percentage of -26.35% and +6.57% respectively.

Safety evaluation: Adverse events were not observed

during the intake of the investigational product.

DISCUSSION

The purpose of this clinical study was to evaluate the effects of Dyglomera®, which is an extract of DG on anthropometric markers, blood lipids, and other variable parameters in overweight and obese subjects. The change of body fat percentage as the primary efficacy evaluation endpoint was validated using the DEXA method.

The results of the DEXA analysis showed that the body fat percentage decreased by 22.85% in the Dyglomera® group and increased by 0.46% in the placebo group after 12 weeks of the study (Table 1). However, the test group showed a greater decrease, showing a statistically significant difference from the placebo group ($p<0.05$).

The intake of Dyglomera® for 12 weeks decreased the body weight by 6.73 kg (Table 2). In contrast, the placebo group showed a weight loss of 0.08 kg ($p<0.05$).

In addition, as body fat mass and weight decreased, BMI, waist circumference, and hip circumference also decreased significantly in the Dyglomera® group compared to the placebo group ($p<0.05$) (Table 3, 4). The blood markers as secondary efficacy evaluation endpoints also showed a significant regression effect in the test group compared to the placebo group ($p<0.05$) (Table 5).

In particular, compared to the placebo group, HDL-cholesterol and adiponectin were increased by 14.36% and 7.92%, respectively, and total cholesterol, LDL-cholesterol, CRP, insulin, and leptin were decreased by 16.87%, 9.24%, 8.30%, 4.37%, and 11.22%, respectively. These results suggest that Dyglomera® effectively modulates factors related to obesity.

Previous research revealed that Dyglomera® inhibited adipogenesis and lipogenesis by regulating AMPK phosphorylation in white adipose tissues of obesity mice and 3T3-L1 adipocytes and promoted lipolysis by increasing the expression of lipolysis-related proteins [33]. In that study, Dyglomera® supplementation significantly reduced plasma glucose, total cholesterol, triglyceride, free fatty acid, and LDL-cholesterol levels while increasing the plasma HDL-cholesterol/LDL-cholesterol ratio in high-fat diet-fed mice.

In this clinical study, by the intake of Dyglomera®, the amount of body fat decreased, and total cholesterol, HDL, and LDL levels were changed similarly to the results of previous animal experiments. This weight loss and reduction in body fat mass are expected to be due to the effect of inhibiting liposynthesis and promoting lipolysis by Dyglomera®.

Adiponectin and leptin are hormones secreted excessively by adipocytes that regulate insulin sensitivity and energy balance [42,43,44]. It has been reported that adiponectin acts directly on the improvement of insulin resistance and has anti-inflammatory and anti-fibrotic actions [45,46]. Adiponectin levels have been reported to be decreased in obese and diabetic patients [47,48]. Several studies have demonstrated that the concentration of adiponectin has a negative correlation with body weight, fat mass, body mass index, and glycated hemoglobin [49]. In this regard, it has been reported that body weight loss increases the concentration of adiponectin in the blood [50].

Leptin is a hormone that plays a key role in the prevention and treatment of obesity by activating the satiety center of the hypothalamus to suppress appetite and promote energy consumption [51,52]. It has been reported that the concentration of leptin in the blood is affected by the amount of body fat, and high blood leptin levels were observed in humans with high body fat mass [53,54].

After 12 weeks of Dyglomera® intake, the blood leptin concentration was significantly decreased compared to the control group. The concentration of adiponectin in the Dyglomera® intake group showed a tendency to increase without significant difference. The changes in the concentrations of adiponectin and leptin in the blood are supposed to be the result of the decrease in body weight and body fat mass by Dyglomera® intake.

In a previous study, the concentration of adiponectin increased, and the concentration of leptin was decreased in obesity-induced mice by supplementation of Dyglomera® [33]. These results support that the changes in blood adiponectin and leptin concentrations in this clinical study are due to

Dyglomera®.

Adverse events were not observed in the Dyglomera® group and the placebo group during the clinical study, Dyglomera® is expected to be a safe food supplement.

CONCLUSION

In summary, Dyglomera® decreases the body weight and body fat and improves the anthropometric and blood factors associated with obesity after 12 weeks of the daily intake of 400 mg of Dyglomera®. The results of DEXA analysis showed that the body weight loss by Dyglomera® intake was accompanied by a decrease in the body fat mass. Dyglomera® can therefore be a good solution for the management of overweight and its complications.

List of abbreviations: ALT: Alanine Transaminase, AST: Aspartate Transaminase, BMI:Body Mass Index, CRP:C-Reactive Protein, DEXA: Dual-Energy X-ray Absorptiometry, DG: *D. glomerata*, LDL: Low-Density Lipoproteins.

Competing interests: Authors have declared that no competing interests exist.

Authors' contributions: Oben: Conceptualization (lead), review and editing (equal). Youovop and Takuissu: writing the original draft (equal). Takuissu and Singh: Methodology (equal). Mbopda, Mbong and Ntentié: review and editing (equal). Azantsa and Nwang: formal analysis (equal).

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REFERENCES

1. Kopelman PG: Obesity as a medical problem. Nature 2000; 404:635-643. DOI: https://doi.org/10.4236/ss.2011.24042
2. Bibbins-Domingo K, Chertow GM, Coxson PG, Moran A, Lightwood JM, Pletcher MJ, Goldman L: Projected effect of dietary salt reductions on future cardiovascular disease. The New England Journal of Medicine 2010, 362:590-599. DOI: https://doi.org/10.1056/nejmoa0907355
3. Kamandloo F, Mirana M, Salamia M: Evaluation of black seed (Nigella sativa L.) cake and its protein in muffins as a valuable potential functional source for obesity control. Food and Functional Food Science in Obesity 202,; 13(6): 7-27. DOI: https://www.doi.org/10.31989/fffso.v1i6.1107
4. Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, Bales VS, Marks JS: Prevalence of obesity, diabetes, and obesity-related health risk factors, JAMA 2003, 289:76–79. DOI: https://doi.org/10.1001/jama.289.1.76
5. Finucane MM, Stevens GA, Cowan MJ, Danaei G, Lin JK, Paciorek CJ, Singh GM, Gutierrez HR, Lu Y, Bahalim AN, Farzadfar F, Riley LM, Ezzati M: Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group. National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. Lancet 2011; 377:557–567. DOI: https://doi.org/10.1016/s0140-6736(10)62037-5
6. Comuzzie AG, Allison DB: The search for human obesity genes. Science 1998, 280:1374-1377. DOI: https://doi.org/10.1126/science.280.5368.1374
7. Lee JH, Reed DR, Price RA: Familial risk ratios for extreme obesity: implications for mapping human obesity genes. International Journal of Obesity and Related Metabolic Disorders 1997, 21:935-940. DOI: https://doi.org/10.1038/sj.ijo.0800498
8. Slochower J, Kaplan SP, Mann L. The effects of life stress and weight on mood and eating: Appetite 1981, 2:115-125. DOI: https://doi.org/10.1016/s0195-6663(81)80005-0
9. Lahti-Koski M, Pietinen P, Heliövaara M, Vartiainen E: Associations of body mass index and obesity with physical activity, food choices, alcohol intake, and smoking in the 1982-1997 FINRISK Studies. American Journal of Clinical Nutrition 2002, 75:809-817. DOI: https://doi.org/10.1093/ajcn/75.5.809
10. Jack BU, Malherbe CJ, Mamushi M, Muller CJF, Joubert E, Louw J, Pheiffer C: Adipose tissue as a possible therapeutic target for polyphenols: A case for Cyclopia extracts as anti-obesity nutraceuticals. Biomedical Pharmacotherapy 2019, 120:109439. DOI: https://doi.org/10.1016/j.biopha.2019.109439
11. Kang JG, Park CY: Anti-obesity drugs: A review about their effects and safety. Diabetes Metabolism Journal 2012, 36:13-25. DOI: https://doi.org/10.4093/dmj.2012.36.1.13
12. Kim KS, Park SW: Drug Therapy for obesity. Korean Journal of Obesity 2012, 21:197-202. DOI: http://dx.doi.org/10.7570/kjo.2012.21.4.197

13. Pari L, Umamaheswari J: Antihyperglycaemic activity of Musa sapientum flowers: effect on lipid peroxidation in alloxan diabetic rats. Phytotherapy Research 2000, 14:1-3. https://doi.org/10.1002/(sici)1099-1573(200003)14:2%3C136::aid-ptr607%3E3.0.co;2-k
14. Valiathan MS, Healing plants: Current Science 1998, 75:1122-1127. DOI:
15. D'Archivio M, Filesi C, Di Benedetto R, Gargiulo R, Giovannini C, Masella R: Polyphenols, dietary sources and bioavailability. Annali dell'Istituto superiore di sanità 2007, 43:348-361.
16. Norouzi M, Pour PM, Asgary S: Camellia sinensis in the form of green and black tea for the primitive prophylactive effect on cardiovascular disease. Food Bioactive Compounds in Cardiovascular Diseases 2022, 1(11): 1-3. DOI: https://www.doi.org/10.31989/fbccd.v1i11.1026
17. Pérez-Jiménez J, Neveu V, Vos F, Scalbert A: A systematic analysis of the content of 502 polyphenols in 452 foods and beverages-An application of the Phenol-Explorer database. Journal of Agriculture and Food Chemistry 2010, 58:4959–4969. DOI: https://doi.org/10.1021/jf100128b
18. Oben J, Bigoga J, Takuissu G, Teta I, Leke R: The acceptability (Star Yellow), a Cameroonian functional food that could curb the spread of the COVID-19 via feces. Functional Foods in Health and Disease 2020, (10)8: 324-329 DOI: https://doi.org/10.31989/ffhd.v10i7.715
19. Otunola GA, Afolayan AJ: In vitro Alpha-amylase inhibition, antioxidant, nutritional and sensory properties of functional spice-blend fortified cookies. Functional Foods in Health and Disease 2022, 12(2): 56-69. DOI: https://www.doi.org/10.31989/ffhd.v12i2.845
20. Mbuya LP: Useful trees and shrubs for Tanzania: Identification, Propagation and management for agricultural and past oral communities. Regional Soil Conservation Unit. Swedish International Development Authority (SIDA); 1994.
21. Fowler DG, Lewis G. Dichrostachys cinerea (L.) Wight & Arn. In: Schmelzer G.H. & Gurib-fakim A. (Editors). Prota 2013; 11(2):Medicinal plants/Plantes medicinales 2.PROTA, Wageningen, Netherlands.
22. Shanmugam NK. Dictionary of Medicinal Plants. Chennai: Kalaiselvi Publications 1989; p.768.
23. Tchiégang C, Mbougueng PD: Chemical composition of spices used in the cooking of nah poh and nkui of western Cameroon. Tropicultura 2005, 23(4):193-200. DOI
24. Orwa C, Mutua A, Kindt R, Jamnadass R, Anthony S: Agroforestree database: a tree reference and selection guide version 4.0. World Agroforestry Centre, Kenya. 2009.
25. Zeid AH, Hifnawy MS, Mohammed RS: Phenolic Compounds and Biological Activities of Dichrostachys cinerea L. Medicinal and Aromatic Plant Science and Biotechnology 2009, 3:42-49.
26. Tillement JP, Albengres E: Pharmacological approach to the rational use of cardiotonic heterosides. Coeur Med Interne 1977, 16(2):239-248.
27. Fankam AG, Kuete V, Voukeng IK, Kuiate JR, Pages JM: Antibacterial activities of selected Cameroonian spices and their synergistic effects with antibiotics against multidrug-resistant phenotypes. BMC Complementary and Alternative Medicine 2011, 11:104. DOI: https://doi.org/10.1186%2F1472-6882-11-104
28. Atsang AKG, Dzeufiet DPD, Foyet HS, Nana P, Sokeng DS, Dimo T, Kamtchouing P: Analgesic and Anti-Inflammatory Activities of Dichrostachys glomerata (Forssk.) Hutch. Fruits Methanolic Extract in Rats. Journal of Physiology and Pharmacological Advances 2012, 2(8):269-276. DOI:
29. Kudi AC, Umoh JU, Eduvie LO, Gefu J: Screening of some Nigerian Medicinal plants for antibacterial activity. Journal of Ethnopharmacology 1999, 67(2):225-228. DOI: https://doi.org/10.1016/s0378-8741(98)00214-1
30. Kuate D, Etoundi BCO, Soukontoua YB, Ngondi JL, Oben JE : Antioxidant characteristics of Dichrostachys glomerata spice extracts. CyTA-Journal of Food 2010, 8:23–37. DOI: https://doi.org/10.1080/19476330903129126
31. Kuate D: Effects of some spices on glucose and lipid metabolism and oxidative stress. Ph.D. Thesis, University of Yaounde, Yaounde, Cameroon. 2010.
32. Kuate D, Etoundi BC, Ngondi JL, Oben JE : Effects of Dichrostachys glomerata spice on cardiovascular diseases risk factors in normoglycemic and type 2 diabetic obese volunteers. Food Research International 2011, 44(5):1197-1202. DOI: https://doi.org/10.1016/j.foodres.2010.09.037
33. Kim HL, Lee SK, Min DE, Choi BK, Lee DR : Anti-obesity effect of Dyglomera® is associated with activation of the AMPK signaling pathway in 3T3-L1 adipocytes and mice with high-fat diet-induced obesity. Molecules 2022, 27(10):3288. DOI: https://doi.org/10.3390/molecules27103288
34. Kuate D, Etoundi BC, Ngondi JL, Muda W, Oben JE : Anti-inflammatory, anthropometric and lipomodulatory effects Dyglomera® (aqueous extract of Dichrostachys glomerata) in obese patients with metabolic syndrome. Functional Foods in Health and Disease 2013, 3:416-427. DOI: http://dx.doi.org/10.31989/ffhd.v3i11.35

35. Kuate D, Kengne A, Dakam W, Etoundi BC, Paka G, Ngondi JL, Oben JE: Effectiveness of Dichrostachys glomerata spice phenolics in reduction of oxidative stress associated with obesity and Type 2 diabetes; a Randomized, double-blind placebo-controlled clinical trial. Journal of Food Research 2013, 2(2):1-10. DOI: http://dx.doi.org/10.5539/jfr.v2n2p1
36. Ramírez-Vélez R, Correa-Bautista JE, González-Ruíz K, Vivas A, García-Hermoso A, Triana-Reina HR: Predictive validity of the body adiposity index in overweight and obese adults using dual-energy X-ray absorptiometry. Nutrients 2016, 8(12):737. DOI: https://doi.org/10.3390%2Fnu8120737
37. Dervaux N, Wubuli M, Megnien JL, Chironi G, Simon A: Comparative associations of adiposity measures with cardiometabolic risk burden in asymptomatic subjects. Atherosclerosis 2008, 201(2):413-417. DOI: https://doi.org/10.1016/j.atherosclerosis.2007.11.032
38. Gómez-Ambrosi J, Silva C, Galofré JC, Escalada J, Santos S, Gil MJ, Valentí V, Rotellar F, Ramírez B, Salvador J, Frühbeck G: Body adiposity and type 2 diabetes: increased risk with a high body fat percentage even having a normal BMI. Obesity 2011, 19(7):1439-1444. DOI: https://doi.org/10.1038/oby.2011.36
39. Dehghan M, Merchant AT: Is bioelectrical impedance accurate for use in large epidemiological studies? Nutrition Journal 2008, 7:26-33. DOI: https://doi.org/10.1186%2F1475-2891-7-26
40. Sun SS, Chumlea WC, Heymsfield SB, Lukaski HC, Schoeller D, Friedl K, Kuczmarski RJ, Flegal KM, Johnson CL, Hubbard VS: Development of bioelectrical impedance analysis prediction equations for body composition with the use of a multicomponent model for use in epidemiologic surveys. American Journal of Clinical Nutrition 2003, 77(2):331-340. DOI: https://doi.org/10.1093/ajcn/77.2.331
41. Prior BM, Cureton KJ, Modlesky CM, Evans EM, Sloniger MA, Saunders M, Lewis RD. In vivo validation of whole-body composition estimates from dual-energy X-ray absorptiometry. Journal of Applied Physiology 1997, 83(2):623–630. DOI: https://doi.org/10.1152/jappl.1997.83.2.623
42. Bradley R, Cleveland K, Cheatham B: The adipocyte as a secretory organ: mechanisms of vesicle transport and secretory pathways. Recent Progress in Hormone Research 2001, 53:329–358. DOI: https://doi.org/10.1210/rp.56.1.329
43. Guerre-Millo M: Adipose tissue and adipokines: for better or worse. Diabetes Metabolism 2004, 30(1):13–19. DOI: https://doi.org/10.1016/s1262-3636(07)70084-8
44. Klaus S: Adipose tissue as a regulator of energy balance. Current Drug Targets 2004, 5(3):241–250. DOI: https://doi.org/10.2174/1389450043490523
45. Marangoni RG, Masui Y, Fang F, Korman B, Lord G, Lee J, Lakota K, Wei J, Scherer PE, Otvos L, Yamauchi T, Kubota N, Kadowaki T, Asano Y, Sato S, Tourtellotte WG, Varga J: Adiponectin is an endogenous antifibrotic mediator and therapeutic target. Scientific Reports 2017, 7(1):1-12. DOI: https://doi.org/10.1038/s41598-017-04162-1
46. Straub LG, Scherer PE: Metabolic messengers: adiponectin. Nature Metabolism 2019, 1(3):334–339. DOI: https://doi.org/10.1038/s42255-019-0041-z
47. Altinova AE, Toruner F, Bukan N, Yasar DG, Akturk M, Cakir N, Arslan M: Decreased plasma adiponectin is associated with insulin resistance and HDL cholesterol in overweight subjects. Endocrinology Journal 2007, 54(2):221-226. DOI: https://doi.org/10.1507/endocrj.k06-021
48. Højlund K, Frystyk J, Levin K, Flyvbjerg A, Wojtaszewski JF, Beck-Nielsen H: Reduced plasma adiponectin concentrations may contribute to impaired insulin activation of glycogen synthase in skeletal muscle of patients with type 2 diabetes. Diabetologia 2006, 49(6):1283-1291. DOI: https://doi.org/10.1007/s00125-006-0240-5
49. Arita Y, Kihara S, Ouchi N, Takahashi M, Maeda K, Miyagawa J, Hotta K, Shimomura I, Nakamura T, Miyaoka K, Kuriyama H, Nishida M, Yamashita S, Okubo K, Matsubara K, Muraguchi M, Ohmoto Y, Funahashi T, Matsuzawa Y: Paradoxical decrease of an adipose-specific protein, adiponectin, in obesity. Biochemical and Biophysical Research Commununications 1999, 257(1):79-83. https://doi.org/10.1006/bbrc.1999.0255
50. Yang WS, Lee WJ, Funahashi T, Tanaka S, Matsuzawa Y, Chao CL, Chen CL, Tai TY, Chuang LM: Weight reduction increases plasma levels of an adipose-derived anti-inflammatory protein, adiponectin. Journal of Clinical Endocrinology and Metabolism 2001, 86(8):3815-3819. DOI: https://doi.org/10.1210/jcem.86.8.7741
51. Jakubowicz D, Froy O, Wainstein J, Boaz M: Meal timing and composition influence ghrelin levels, appetite scores and weight loss maintenance in overweight and obese adults. Steroids 2012, 77(4):323-331. DOI: https://doi.org/10.1016/j.steroids.2011.12.006
52. Hosogai N, Fukuhara A, Oshima K, Miyata Y, Tanaka S, Segawa K, Furukawa S, Tochino Y, Komuro R, Matsuda M, Shimomura I: Adipose tissue hypoxia in obesity and its impact on adipocytokine dysregulation. Diabetes 2007, 56(4):901-911.

DOI: https://doi.org/10.2337/db06-0911

53. Blum WF, Englaro P, Hanitsch S, Juul A, Hertel NT, Müller J, Skakkebaek NE, Heiman ML, Birkett M, Attanasio AM, Kiess W, Rascher W: Plasma leptin levels in healthy children and adolescents: dependence on body mass index, body fat mass, gender, pubertal stage, and testosterone. The Journal of Clinical Endocrinology and Metabolism 1997, 82(9):2904-2910. DOI: https://doi.org/10.1210/jcem.82.9.4251
54. Scholz GH, Englaro P, Thiele I, Scholz M, Klusmann T, Kellner K, Rascher W, Blum WF: Dissociation of Serum Leptin Concentration and Body Fat Content During Long Term Dietary Intervention in Obese Individuals. Hormone and Metabolic Research 1996, 28(12):718-723. DOI: https://doi.org/10.1055/s-2007-979886