ORIGINAL RESEARCH

The Significance and Correlation Analysis of Serum Uric Acid and High Sensitivity CRP in the Energy-Limiting Balance Intervention in Obese Patients

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ABSTRACT

Objective • Our aim was to explore the effects of the energy-limiting balance intervention on serum uric acid (SUA) and high sensitivity C-reactive protein (hs-CRP) and analyze the correlation between the two.

Methods • Retrospectively chosen study patients were 98 obese individuals who received diagnoses and care in Xuanwu Hospital Capital Medical University between January 2021 and September 2022. The patients were divided into the intervention group and the control group via random number table, with 49 patients in each group. The control group received standard food interventions, while the intervention group received minimal energy balance interventions. The clinical outcomes in both groups were compared. We also compared patients' pre- and post-intervention levels of SUA, hs-CRP, and markers of glucose and lipid metabolism were assessed. Analysis was done on the relationship between markers of glucose and lipid metabolism and SUA and hs-CRP levels.

Results • Patients in the intervention and control groups had respective ineffective rates of 6.12% and 20.41%, effective rates of 51.02% and 57.14%, substantial effective rates of 42.86% and 22.45% and overall effective rates of 93.88% and 79.59%. The intervention group's overall effective rate was substantially greater than the control group's rate ($P < .05$). After the intervention, patients in the intervention group had markedly decreased SUA and hs-CRP levels than patients in the control group ($P < .05$). Prior to the intervention, there was no clinically meaningful discrepancy between the two groups in terms of fasting blood glucose, insulin, glycated hemoglobin (HbA_{1c}) or 2 hours postprandial blood glucose ($P > .05$).

Following the intervention there was a statistically significant discrepancy between the intervention group and the control group in terms of fasting blood glucose, insulin, HbA_{1c} and 2 hours postprandial blood glucose ($P < .05$). According to a Pearson correlation study, high-density lipoprotein (HDL) was negatively correlated with the SUA levels and positively correlated with fasting blood sugar, insulin, triglycerides, total cholesterol and low-density lipoprotein (LDL). Before the intervention, there was no clinically meaningful variation in the intervention or control groups in triglycerides, total cholesterol, LDL or HDL ($P > .05$). Following the intervention, patients in the intervention group had markedly decreased triglycerides, total cholesterol and LDL levels than patients in the control group, while their HDL levels had substantially increased compared with the control group ($P < .05$). Fasting blood sugar, insulin, triglycerides and LDL all had a positive correlation with their SUA levels ($P < .05$). The amount hs-CRP was inversely correlated with HDL ($P < .05$) and positively correlated with fasting blood glucose, insulin, 2h postprandial blood glucose, HbA_{1c}, triglycerides and LDL.

Conclusion • An energy-limiting balance intervention can effectively reduce SUA and hs-CRP, regulate the metabolism of glucose and lipid and were closely related. (*Altern Ther Health Med.* 2023;29(5):32-39).

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INTRODUCTION

Obesity is the 5th leading cause of mortality worldwide and affects approximately 13% of adults, which equates to approximately 650 million individuals. The prevalence of obesity has risen significantly as living standards have improved.[1] Obesity is a significant risk factor for numerous diseases, including type 2 diabetes (T2D) among Chinese children younger than 18 years was 30.1% and 11.9%, respectively, in 2012, according to a report on the nutrition

and chronic illnesses of Chinese residents,[3] which was an increase of 7.3% and 4.8%, respectively, from 2002. In addition, adult central obesity is becoming more prevalent, with an increasing average waist circumference.[4] The incidence of hypertension, CHD and other cardiovascular diseases (CVD) caused by overweight and obesity are showing a trend towards affecting younger people every year. Therefore, discovering scientific and rational approaches to prevent and manage weight gain is crucial.

Patients can manage their weight by adopting a range of strategies, including weight-loss surgery, medications and positive lifestyle changes. Reducing caloric intake and boosting energy expenditure is essential regardless of the treatment strategy employed.[5] Self-monitoring of diet and exercise is a powerful tool for behavioral modifications aimed at controlling weight. A balanced energy diet, one of the dietary weight loss methods recommended by Chinese nutritional experts, restricts energy intake while ensuring basic nutritional requirements for the body.[6] The energy balance diet is a universal diet suitable for weight management among adolescents, older individuals, pregnant women, menopausal women, individuals who lost weight after being obese and others.[7] Calorie restriction has been found to effectively improve glomerular filtration, insulin sensitivity and the risk for CVD in patients with abdominal obesity.[8] SUA and hs-CRP have been identified as important biomarkers in overweight and obese individuals, as they are closely related to inflammation and metabolic disorders. Elevated SUA levels are known to be associated with an increased risk for metabolic syndrome, hypertension and CVD. Meanwhile, elevated hs-CRP is a well-established marker of chronic systemic inflammation, which has been shown to be closely linked to the pathogenesis of obesity-related comorbidities such as T2D, atherosclerosis and CVD. Therefore, evaluating changes in these biomarkers following energy-limiting balanced interventions has significant clinical implications.

In this study, we retrospectively selected obese patients diagnosed and treated in Xuanwu Hospital Capital Medical University, who received energy-restricting balanced interventions, with the aim of exploring the effect of energy-restricting balanced interventions on SUA and hs-CRP), as well as analyzing the correlation between the two. This study may provide some relevant references for clinical disease treatments.

DATA AND METHODS

General Information

This study retrospectively selected 98 obese patients who received diagnosis and treatment at our hospital between January 2021 and September 2022. Divided into two groups according to whether they received energy restriction balance intervention, 49 people in each group. Mean patient age was 41.54 ± 4.86 years, average duration of illness was 4.52 ± 2.85 years, and mean body mass index (BMI) was (30.75 ± 1.18) kg/m2 in the intervention group, which consisted of 27 men and 22 women. In the control group, there were 30 men and 19 women, and the mean age was 41.95 ± 5.19 years, average duration of illness was (5.59 ± 3.44) years and mean BMI was (30.96 ± 2.08) kg/m^2.

Inclusion criteria

Patients were included in the study if they (1) met the diagnostic and treatment criteria for obesity; (2) had a BMI ≥28 kg/m^2 and abdominal circumference ≥80 cm; (3) had a relatively stable mental state and could cooperate with the research and treatment.

Exclusion criteria

Patients were excluded from the study if they (1) refused to cooperate; (2) had conducted weight-loss related behaviors such as drugs or surgery within 2 months of participating in the study; (3) had incomplete data; (4) had heart, liver or renal disease or other clear health problems.

The study and procedures were approved by the hospital ethics board, and complied with medical ethics. Age, sex, BMI and other factors were similar in both groups ($P > .05$).

Methods

The control group was given routine dietary interventions, while the intervention group received an energy-limiting balanced diet intervention.[10] A routine diet intervention typically involves general guidelines for healthy eating that include various foods from the major food groups such as fruits, vegetables, grains, low-fat dairy products and lean protein. The goal is often to promote overall health, as well as weight loss. An energy-limiting balanced diet, on the other hand, is a specific type of diet plan designed to create a caloric deficit, meaning the patient consumes fewer calories than their body burns, which leads to weight loss. This type of diet is usually designed by a healthcare professional and includes specific instructions about how much of each type of food to eat to achieve the desired caloric deficit. It may also involve monitoring the number of calories consumed per meal or per day.

In summary, while routine diet interventions are generally focused on promoting overall health and wellness, an energy-limiting balanced diet is specifically aimed at helping patients lose weight by reducing caloric intake.

Body composition was tested with the InBody Body Composition Manager (InBody720, InBody USA, Los Cerritos, California USA) at baseline and after the intervention. Weight and other body composition measurements were collected with patients wearing minimal clothing and no shoes, and the patients' BMI was calculated. Blood samples for biochemical measurement were obtained before and after the 8-week intervention. The serum was separated by centrifugation and stored in equal parts at -80°C until further analysis. Patients were randomly assigned to one of the two groups. Prior to the study, all patients attended a mandatory nutrition meeting with a dietitian who provided detailed instructions on maintaining accurate records of dietary food intake. According

to the principles of healthy nutrition, carbohydrates, fats and protein should account for 50%, 20% and 30% of total energy intake, respectively, and carbohydrate intake should be strictly restricted. Both groups underwent an 8-week intervention, and data collection followed the same procedures as the baseline test. The tests were conducted by the same researcher to ensure reliability.

Outcome Indicators

The study analyzed the clinical effects of treatment for patients and classified them into marked effect, effective, and ineffective. To be considered effective, patients' indicators needed to basically return to normal, and they needed to lose at least 5 kilograms in weight. Improvement in all outcomes along with weight loss of at least 3 kilograms in GI tract was also considered effective. If there was no clear improvement in all indicators, or even an increase in weight, the treatment was considered invalid.[11]

To calculate the BMI, we used the standard formula of weight divided by height squared, where weight is measured in kilograms (kg) and height is measured in meters (m). The formula is as follows:

$$BMI = Weight\ (kg) / Height^2\ (m)$$

UA and hs-CRP levels were measured using an enzyme-linked immunosorbent test to determine how the levels changed before and after the intervention.

Detection of glucose and lipid metabolism indicators. The patients' fasting blood glucose, 2h postprandial blood glucose, glycosylated hemoglobin (HbA_{1c}), insulin, triglycerides, total cholesterol, low-density lipoprotein (LDL), and high-density lipoprotein (HDL) were all measured using an automatic biochemical analyzer.

Statistical Analysis

In this investigation, the clinical effects and other data were reported as cases (%) and the χ^2 test was applied. The results were expressed as $\bar{x} \pm s$ and all corresponded to normal distribution, including UA, hs-CRP and glycolipid metabolism markers. The measurement data in the both groups were analyzed using independent sample *t* test. Correlation analysis was conducted via the Pearson correlation test. The statistical results ($P < .05$) were considered highly meaningful in this study since they were obtained using IBM® SPSS22.0 software.

RESULTS

Clinical Effect Analysis of Both Groups of Patients

Patients in the intervention and control groups had respective ineffective rates of 6.12% and 20.41%, effective rates of 51.02% and 57.14%, substantial effectiveness rates of 42.86% and 22.45% and efficient operational rates of 93.88% and 79.59%. The intervention group's overall effectiveness rate was substantially greater than the control group's ($P < .05$) rate (see Table 1).

Table 1. Comparison of Clinical Effects in Both Groups [cases (%)]

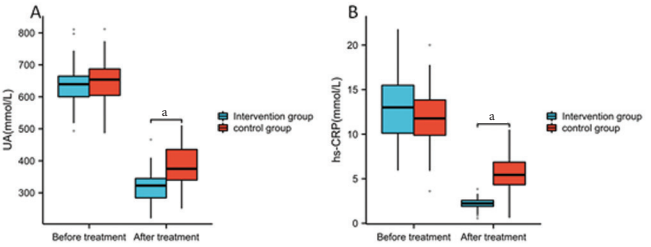
Group	n	Invalid	Effective	Marked Effect	Efficiency
Intervention	49	3 (6.12)	25 (51.02)	21 (42.86)	46 (93.88)
Control	49	10 (20.41)	28 (57.14)	11 (22.45)	39 (79.59)
χ^2	4.356				
P value	.037				

Table 2. Comparison of Serum Uric Acid and High Sensitivity C-reactive Protein Levels in Both Groups ($\bar{x} \pm s$)

Group	n	Serum UA (mmol/L)		High sensitivity CRP (mg/L)	
		Before intervention	After intervention	Before intervention	After intervention
Intervention	49	637.58 ± 63.06	320.02 ± 53.14	12.81 ± 3.32	2.19 ± 0.64
Control	49	647.14 ± 68.64	386.48 ± 49.92	11.80 ± 3.27	5.60 ± 2.21
t		0.718	6.381	1.517	10.375
P value		.475	.001	.133	.001

Abbreviations: CRP, C-reactive protein; UA, uric acid.

Figure 1. Comparison of SUA and hs-CRP levels in both groups. (**1A**) comparison of SUA levels in both groups; (1B) comparison of hs-CRP levels in both groups.



[a]$P < .001$, Compared with the intervention group

Abbreviations: hs-CRP, high sensitivity-reactive protein; SUA, serum uric acid.

Analysis of Changes in SUA and hs-CRP in Both Groups

Prior to the intervention, there was no clinically meaningful variation in UA or hs-CRP levels in the intervention or control group ($P > .05$). After the intervention, patients in the intervention group had substantially lower SUA and hs-CRP levels than patients in the control group ($P < .05$) (see Table 2 and Figure 1).

The normal range for SUA levels can vary slightly depending on the laboratory that performs the analysis, but typically falls within 3.5 to 7.2 mg/dL in men and 2.6 to 6.0 mg/dL in women. Higher SUA levels can be indicative of hyperuricemia, which has been associated with an increased risk for gout, CVD and metabolic syndrome.

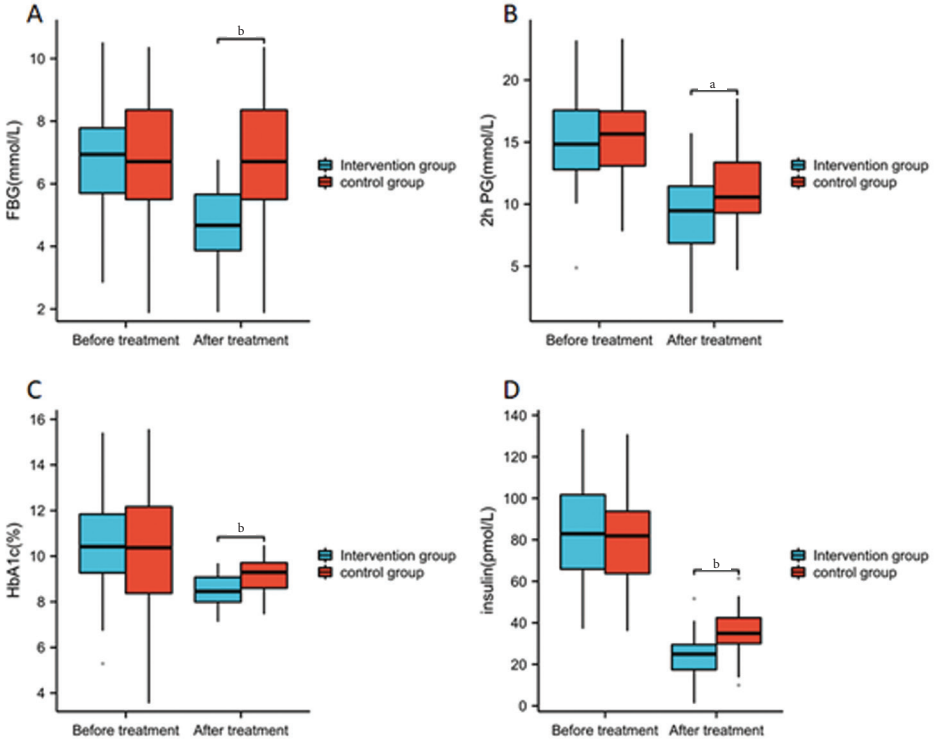
As for hs-CRP levels, the normal range is typically <1.0 mg/L. Elevations in hs-CRP are often indicative of inflammation and have been associated with an increased risk for CVD and other chronic conditions. Thus, monitoring hs-CRP levels

Table 3. Comparison of Blood Glucose Levels in Both Groups ($\bar{x} \pm s$)

Group	n	Fasting blood glucose (mmol/L)		Blood glucose 2h after a meal (mmol/L)		HbA_{1c} (%)		Insulin (pmol/L)	
		Before	After	Before	After	Before	After	Before	After
Intervention	49	6.69 ± 1.63	4.62 ± 1.27	15.32 ± 3.72	9.16 ± 3.02	10.45 ± 2.16	8.52 ± 0.88	83.50 ± 22.27	24.28 ± 9.20
Control	49	6.84 ± 1.89	5.20 ± 1.19	15.44 ± 3.32	11.25 ± 3.15	10.26 ± 2.55	9.16 ± 0.75	80.52 ± 27.96	36.03 ± 10.03
t		0.421	2.333	0.169	3.337	0.398	3.875	0.584	6.043
P value		.675	.022	.867	.001	.692	.001	.561	.001

Abbeviations: HbA_{1c}, glycated hemoglobin.

Figure 2. Comparison of blood glucose levels in both groups. (**2A**) Comparison of fasting blood glucose levels in both groups; (**2B**) comparison of blood glucose levels 2h postpandial in both groups; (**2C**) comparison of HbA_{1c} levels in both groups; (**2D**) comparison of insulin levels in both groups.



[a]$P < .01$, Compared with the intervention group
[b]$P < .001$, Compared with the intervention group

Abbreviations: HbA_{1c}, glycated hemoglobin.

can be a useful tool for assessing the risk for these conditions in high-risk populations or for tracking the effectiveness of interventions designed to reduce inflammation.

Analysis of Changes in Blood Glucose Levels in Both Groups

Before the intervention, there was no clinically meaningful discrepancy between the intervention and control groups in terms of fasting blood glucose, insulin, HbA_{1c} or 2h postprandial blood glucose ($P > .05$). After the intervention, patients in the intervention group had substantially lower fasting blood glucose, insulin, HbA_{1c} and 2h postprandial blood glucose levels than patients in the control group ($P < .05$) (see Table 3 and Figure 2).

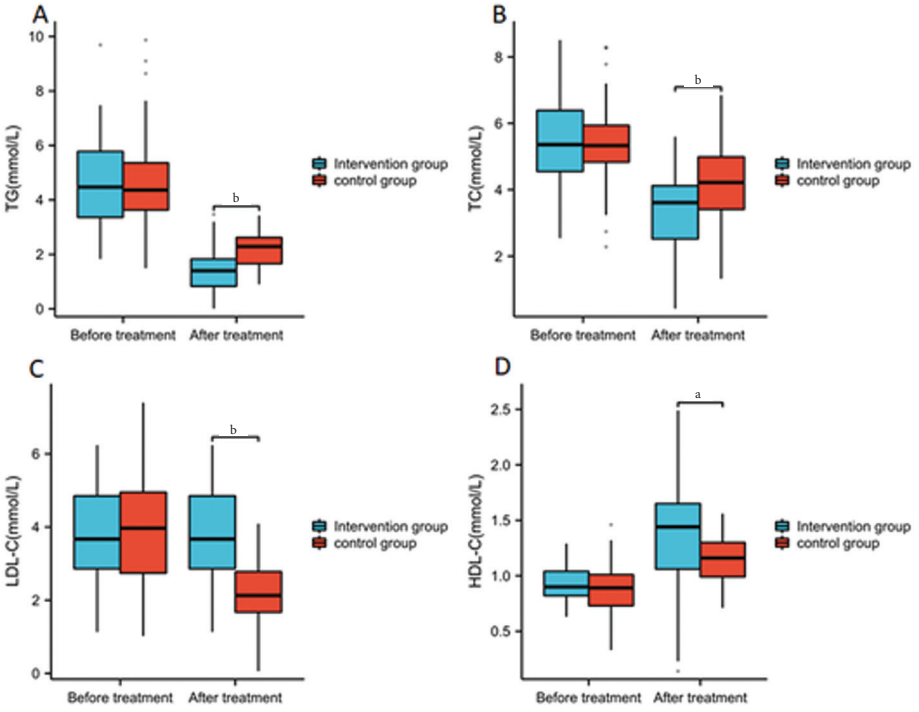
Analysis of Changes in Blood Lipid Levels in Both Groups

Before the intervention, there was no clinically meaningful variation in the intervention vs the control group in triglycerides, total cholesterol, LDL or HDL ($P > .05$). Following the intervention, patients in the intervention group had markedly decreased triglycerides, total cholesterol and LDL levels compared with the control group, while their HDL levels were massively increased compared with the control group ($P < .05$) (see Table 4 and Figure 3).

Table 4. Analysis of Changes in Blood Lipid Levels in Both Groups ($\bar{x} \pm s$)

Group	n	Triglycerides (mmol/L)		Total cholesterol (mmol/L)		Low-density lipoprotein (mmol/L)		High-density lipoprotein (mmol/L)	
		Before	After	Before	After	Before	After	Before	After
Intervention	49	4.73 ± 1.62	1.44 ± 0.95	5.46 ± 1.35	3.38 ± 1.11	3.75 ± 1.34	1.81 ± 0.43	0.93 ± 0.16	1.38 ± 0.53
Control	49	4.61 ± 1.76	2.21 ± 0.64	5.42 ± 1.20	4.16 ± 1.07	3.91 ± 1.60	2.15 ± 0.80	0.88 ± 0.23	1.14 ± 0.21
t		0.351	4.706	0.155	3.541	0.537	2.621	1.249	2.947
P value		.726	.001	.877	.001	.593	.010	.215	.004

Figure 3. Comparison of blood lipid levels in both groups. (**3A**) Comparison of triglyceride levels in both groups; (**3B**) comparison of total cholesterol levels in both groups; (**3C**) comparison of low-density lipoprotein levels in both groups; (**3D**) comparison of high-density lipoprotein levels in both groups.



[a]$P < .01$, Compared with the intervention group
[b]$P < .001$, Compared with the intervention group

Correlation Analysis of SUA and Glucose and Lipid Metabolism Indicators in Obese Patients

According to Pearson correlation analysis, fasting blood sugar, insulin, triglycerides and LDL were all positively correlated with SUA levels ($P < .05$) (see Table 5 and Figure 4).

Analysis of Correlation Between hs-CRP and Glucose and Lipid Metabolism Indicators in Obese Patients

hs-CRP levels were favorably correlated with fasting blood sugar, insulin, 2hr postprandial glucose, HbA_{1c}, triglycerides and LDL, and inversely linked with HDL, according to Pearson correlation analysis ($P < .05$) (see Table 6 and Figure 5).

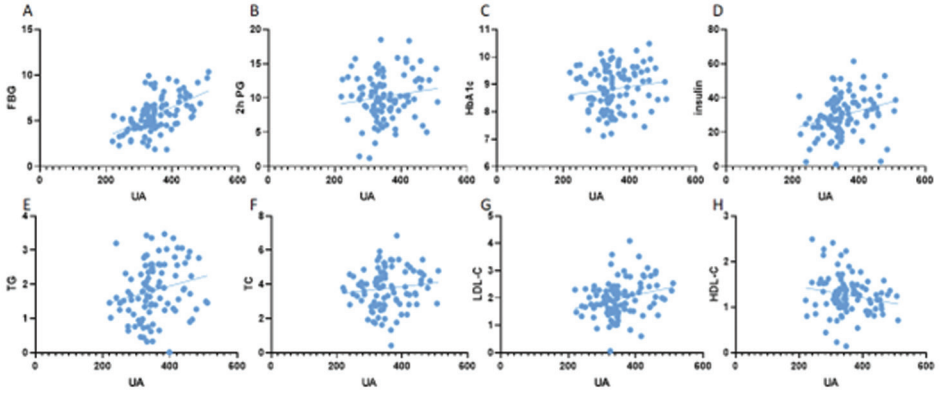
DISCUSSION

Obesity is a complex, chronic condition that can be prevented. It is characterized by an abnormal or excessive accumulation of body fat, and clinical practice and medical

Table 5. Correlation Analysis of Serum Uric Acid and Glucose and Lipid Metabolism Indices in Obese Patients

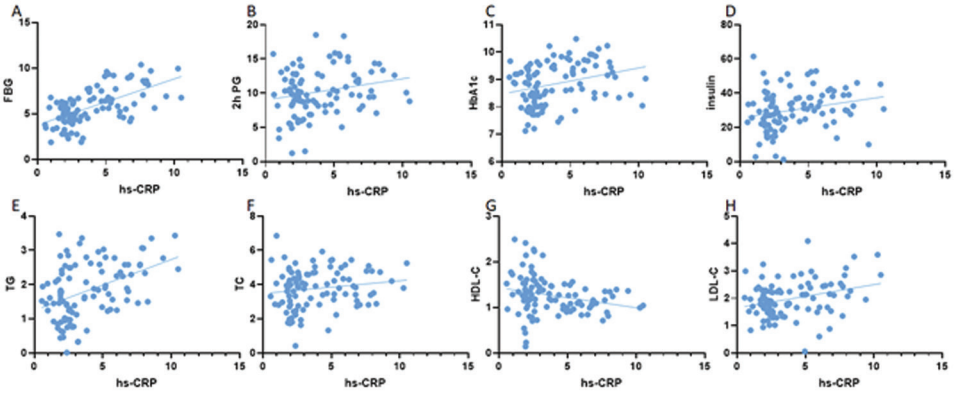
Index	Serum Uric Acid	
	r	*P* value
Fasting blood glucose	0.530	.001
2h postprandial blood glucose	0.144	.159
Glycated hemoglobin	0.135	.186
Insulin	0.282	.005
Triglycerides	0.212	.037
Total cholesterol	0.119	.245
Low-density lipoprotein	0.256	.011
High-density lipoprotein	-0.187	.066

Figure 4. Correlation analysis of SUA and glucose and lipid metabolism indices in obese patients. (**4A**) The relationship between SUA and fasting blood sugar; (**4B**) the relationship between SUA and postprandial blood sugar levels; (**4C**) the relationship between SUA and HbA_{1c}; (**4D**) the relationship between SUA and insulin; (**4E**) relationship between SUA and triglycerides; (**4F**) the relationship between SUA and total cholesterol; (**4G**) the relationship between LDL and SUA; (**4H**) the relationship between HDL and SUA.



Abbreviations: HbA_{1c}, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SUA, serum uric acid.

Figure 5. Analysis of correlation between hs-CRP and glucose and lipid metabolism indices in obese patients. (**5A**) The relationship between hs-CRP and fasting blood glucose; (**5B**) the relationship between hs-CRP and 2h postprandial blood glucose; (**5C**) the relationship between hs-CRP and HbA_{1c}; D: The relationship between hs-CRP and insulin; (**5E**) the relationship between hs-CRP and triglycerides; (**5F**) the relationship between hs-CRP and total cholesterol; (**5G**) the relationship between hs-CRP and LDL; (**5H**) the relationship between hs-CRP and HDL.



Abbreviations: HbA_{1c}, glycated hemoglobin; HDL, high-density lipoprotein; hs-CRP, high-intensity C-reactive protein.

Table 6. Analysis of Correlation Between High-Sensitivity C-reactive Protein and Glucose and Lipid Metabolism Indices in Obese Patients

	hs-CRP	
Index	***r***	***P* value**
Fasting blood glucose	0.610	.001
2h postprandial blood glucose	0.217	.032
Glycated hemoglobin	0.289	.004
Insulin	0.236	.019
Triglycerides	0.428	.001
Total cholesterol	0.152	.136
Low-density lipoprotein	0.302	.003
High-density lipoprotein	-0.246	.015

Abbreviations: hs-CRP, high-sensitivity C-reactive protein.

recommendations use objective measures such as BMI and waist circumference to evaluate weight status and abdominal obesity.[11] Research has shown that obesity is caused by an imbalance between energy intake and energy expenditure, leading to excessive weight gain.[12] Moreover, numerous studies have confirmed the association between obesity and increased risk for CVD, diabetes, certain cancers and musculoskeletal disorders.[13-14] Obesity not only affects individuals and families but also has significant economic impacts. Therefore, it is crucial to ensure that energy intake is balanced during weight intervention. A balanced and sustainable diet is recommended in obese patients to promote both health and environmental well-being.[15]

In our study, patients received energy-restricted interventions, and the results demonstrated a significant

improvement in treatment outcomes in the intervention group compared with the control group. Thus, energy-restricted interventions have positive effects on controlling patients' weight.

UA, an extracellular antioxidant, is associated with salt sensitivity, fat storage and production, all of which are related to obesity.[16] Elevated SUA increases the incidence of metabolic syndrome, diabetes, kidney stones and other diseases.[16] Some studies have confirmed that obesity, especially abdominal obesity, is an independent risk factor for hyperuricemia.[17] Moreover, research has shown that there is a significant association between SUA levels and BMI; obesity is also an independent risk factor for high UA levels.[18] Meta-analyses have consistently found that obesity is a risk factor for gout, and overweight and obesity are linked to an increased occurrence of gout. Obese patients consume more calories than they burn, resulting in the deposition of excess fat under the skin, abdomen or internal organs. Hyperactive purine synthesis and increased UA production are observed due to the increased energy. In addition, the acid metabolite of fat decomposition may inhibit UA excretion, indirectly increasing SUA levels.[19]

Obesity can also cause insulin resistance, which directly affects the proximal convoluted tubules of the kidney, leading to increased UA levels. Furthermore, insulin resistance can activate the renin-angiotensin-aldosterone system, decreasing renal blood flow and thus UA, ultimately increasing SUA.[20-21]

Adipose tissue is an important endocrine organ, and secreted fat can play a crucial role in metabolic syndrome; hyperuricemia and metabolic syndrome components are closely related and interactive.[22] Many studies have demonstrated that diet plays an important role in regulating immune function and inflammatory responses. Chronic low-grade inflammation is the underlying cause of many pathological conditions associated with human obesity and insulin resistance, and studies have reported that obesity and chronic low-grade inflammation are linked.[25] High BMI and body fat accumulation are significant predictive indicators of metabolic disorder. Obese individuals have higher levels of pro-inflammatory protein/cytokine compared with individuals of normal weight. Inflammatory factors are produced by adipocytes, as well as macrophages and lymphocytes in mesenteric adipose tissue. In addition, adipocytokines are overproduced in mesenteric adipose tissue in patients with inflammatory bowel disease. Thus, with an increase in adipose tissue, mesenteric thickening and inflammatory nodules occur, triggering a systemic acute phase reaction.[26]

hs-CRP is an acute-phase protein and a marker and mediator of inflammatory processes, but it can also affect adipose factors. Some studies have found that hs-CRP levels differed in patients with distinct nutritional statuses. The results of multivariate regression analysis showed that the metabolic health of obese patients was closely related to the level of hs-CRP. Furthermore, the level of CRP in obese patients can be significantly decreased after a caloric restriction diet. Similar to the results of this study, energy-restricted interventions can significantly reduce SUA and hs-CRP levels. The reason for this may be that energy-restricted interventions can improve the endocrine system, regulate the effects of hs-CRP on adipocytes, control obesity, affect SUA levels, and reduce the risk for hypertension and other diseases.

The decomposition of fat into glycerol and fatty acids can result in the production of sugar via various pathways. Disorder of fat metabolism can lead to hyperlipidemia, while disorder of glucose metabolism can cause hyperglycemia, and both conditions can affect each other.[28] In this study, we analyzed the effects of an energy-restricted intervention on the glucose and lipid metabolism of obese patients. Our results suggest that this intervention can effectively regulate these metabolic processes. The disorder of glucose and lipid metabolism poses a significant risk to human health and life and is linked to insulin resistance, oxidative stress, chronic inflammation, neuroendocrine dysfunction and other pathologies.[29-30] The mechanism underlying the energy-restricted intervention's ability to regulate glucose and lipid metabolism may be related to limiting energy intake, regulating chronic inflammation, improving insulin sensitivity and other factors.

Furthermore, we found that SUA levels are closely related to hs-CRP levels and the indicators of glucose and lipid metabolism. Therefore, detecting changes in these indicators can help evaluate the patient's condition and response to treatment. Our study indicates that Gintervention of can effectively reduce SUA and hs-CRP levels, as well as regulate glucose and lipid metabolism; however, the effectiveness of this intervention may differ from drug-based interventions due to differences in patient metabolism and timing of the intervention. Future research could extend the intervention period and examine different intervention times to better serve this population.

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