INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 18, No. 3, p. 10-17, 2021

RESEARCH PAPER OPEN ACCESS

Obesity can be prevented by physical training and diet containing *Solanum aethiopicum* Shum fruit

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Key words: *Solanum aethiopicum* fruit, Diet, Physical training, Obesity, Prevention, Rat.

http://dx.doi.org/10.12692/ijb/18.3.10-17 Article published on March 16, 2020

Abstract

Two-thirds of the global disease can be attributable to obesity and its complications. This study was carried out to investigate the effects of endurance training and diet containing *Solanum aethiopicum* Shum fruit (SASF) consumption on obesity prevention. Twenty-four Wistar male rats were grouped (6 per group) according to the physical training and SASF feeding: group 1 (control), group 2 (trained and consumed), group 3 (trained), group 4 (consumed). Parameters of nutritional behaviour, stomach wall weight and obesity biomarkers were recorded. The animals fed on a diet containing SASF showed a significant decrease in total cholesterol, triglycerides and LDL-cholesterol, and an increase in HDL-cholesterol and testosterone. From animals submitted to endurance training only, a significant decrease in total cholesterol and LDL-cholesterol and increase in testosterone, without statistical changes in HDL-cholesterol and triglycerides was observed. The rats were physically trained and fed on an experimental diet containing SASF limited body and abdominal wall weights, improved lipid profile and testosterone towards obesity prevention. In the present study, endurance exercise and diet containing SASF prevented obesity in rats. We conclude that the promotion of durable health could depend on adapted physical activity and a diet containing raw vegetables with a low glycaemic index.

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Introduction

The obesity crisis is amongst the most important health problem that humanity is faced with nowadays. Obesity is stated, for a body mass index greater than or equal to 30.0, and it affects both adults and children in both advanced and developing countries. Borg *et al.* (2005) discovered that the global incidence of obesity has increased to more than 75% since 1980, while in the last twenty years, it has tripled in developing countries and particularly, in low-income countries. Sub-Sahara African countries are faced with two nutritional problems: undernutrition which is decreasing and overnutrition which is instead on the rise. According to the World Health Organization, by 2020, two-thirds of the global disease can be attributable to obesity and its complications.

Many factors may cause obesity in low-income countries: availability and advertising of processed foods rich in sugar, fat, salt; reduction of physical activity due to the decreasing of playtime in school and after work, accessibility of both cars and motorbikes, internet, mobile phone, computer games and television. Other potential factors that can cause obesity are alcohol consumption, stress, pregnancy, side effects of drugs, low cost of fast-foods, reduction in_smoking_rates and genetics. Moreover, the import of high-fat foods and their low cost is considered sufficient enough to explain the rise of overweight and obesity in low-income countries (FAO, 2006).

Obesity is a condition where there is an excessive accumulation of fat in the body that results in weight gain. There are two types of body fats namely: the essential and the storage fats (Polikandrioti and Stefanou, 2009). The essential fat is used for the body functions and includes the female fat which is stored in the breasts and hips. In contrast, storage fat is stored mainly in the subcutaneous tissue as a result of the difference between energy intake and energy expenditure. The fat distribution differs in Central (Android type) and Regional (or female type). Central obesity is characterized by the location of the fat in the upper torso and mainly in the abdomen known as male type, but it is now common in both male and female populations. Scientific evidence suggests that android obesity is associated with greater health risks compared to total obesity (Grundy, 2006; Nibedita *et al.*, 2014). The health implications of obesity or overweight are the increasing incidence of hypertension, cardiovascular diseases, gallstone, certain types of cancers; diabetes mellitus type 2, reduced quality of life compared to non-obsessed individuals, biochemical disorders (atherosclerosis, hyperglycaemia and dyslipidaemia) as well as higher rates of sudden death (Vitale *et al.*, 2006). Many studies have shown that there is a strong association between obesity and cardiovascular Diseases (Jagatheesan and Vivek, 2014).

Different methods including lifestyle changes (physical exercise, diet, drugs and behaviour) have been used to fight against obesity or overweight and its complications. Physical exercise has been considered as an important mean to fight against obesity or overweight as well as cardiovascular diseases (Derosa and Maffioli, 2011).

Drug usage is another way to combat obesity. However, drugs such as amphetamines, rimonabant and sibutramine have been withdrawn because of their adverse effects; however, only orlistat is tolerated as anti-obesity drugs (Hasani-Ranjbar *et al.*, 2013).

A recent review suggests that herbal medicines are growing in interest as an effective option to reduce body weight and body fat [10]. Traditionally, the decoction of *Solanum aethiopicum* Shum fruits (SASF), so-called "*Mendim me zon*" in Southern Cameroon is consumed before or after meals to limit body fat accumulation. There is evidence that physical activity combined with therapy behaviour is more effective for weight loss than therapy behaviour or a low-fat di*et al*one (Curioni & Lourenco, 2005; NICE, 2006). However, disappointing results after cessation; the lifestyle modifications or pharmacotherapies suggest that prevention is the best way to control this global health concern. Thus, in this work, the animal experiment was carried out to examine the effects of physical exercise combined with the diet containing SASF on the prevention of central obesity. Moreover, we also evaluated this effect on the biomarkers of cardiovascular diseases.

Materials and methods

Solanum aethiopicum Shum fruits

The fruit material was collected from *S. aethiopicum* Shum plant, in October, growing in the locality of Ngaoundéré, Adamawa Region, Cameroon, altitude 3,640 feet, located at 7°24'.730N and 13°33'.001E (GPS, Garmin version 2.11). A voucher specimen (N°HNC/14610 dated 25-08-2009) has been deposited at the National Herbarium of Institute of Research for Agricultural Development, Yaoundé, Cameroon. The ripened fruits were sorted (1–1.5 cm of diameter), washed (tap water), disinfected (2% sodium hypochlorite), rinsed (distilled water), cut, dried (40°C/24 h, vegetable dryer) and ground (vegetable grinder, the particle of 1 mm). Resulting SASF powder was used as an ingredient for the formulation of animal diet.

Animals and diet

The animals were treated following the laboratory animal guidelines concerning the care and use of animals as prescribed by the American Institute for Laboratory Animal Research Council (ILARC, 2011). Briefly, a total of 24, 10-week-old, Wistar male rats were used in the experiment. The rats were divided into four different groups of six. They were randomly housed with six in each plastic cage, under controlled conditions of temperature, humidity and light (12-h light-dark cycle, 23°C ambient temperature and 60% humidity), and free access to food and water. The animals of the first (control) and third group (test 2) were fed with basal diet (19 % of fish, 45 % of maize flour, 5 % of bran, 25 % of palm oil, 5 % of minerals and 1 % of NaCl). The rats of the second (test 1) and fourth (test 3) groups were fed with a diet containing 5 % SASF; the composition of other ingredients was 19 % of fish, 40 % of maize flour, 5 % of bran, 25 % of palm oil, 5 % of minerals and 1 % of NaCl. The second and third groups were submitted to endurance effort using rotarod.

Physical training

Rats of second and third groups (tests 1 & 2) were trained for five days on the Rotarod, to reduce their anxiety levels before testing. The rats were placed on the roller lane of the Rotarod with a diameter of 7 cm set at 16 revolutions per min (model PBS 12V DC 81/WW, Harvard apparatus, from Panlab) for four animals. During the assay, animals continuously walked four times weekly on the horizontal rotating rod set at 16 revolutions per min. When an animal dropped safely or changed direction on the roller lane, it was immediately placed to follow the walk.

The training session was stopped when the fatigue signs such as time of falls or direction changes appeared within ten seconds three times in the same animal. The training and feeding period lasted for 20 days, during which the mean of water intake, food intake and body weight were measured.

Collection of samples from sacrificed animals

At the end of the assay, they were sacrificed under anaesthesia (diethyl-ether), the blood was collected from the jugular vein, and the whole organs (testis, kidneys, heart and liver) were rapidly removed and weighed. The abdominal wall was also excised and weighed. The blood was centrifuged at 3500 x g for 10 min at 5°C, and the resulting serum was used for biochemical analysis.

Biochemical analysis

The serum concentration of triglyceride and total cholesterol were enzymatically measured using commercial kits. HDL was determined using commercial kits in the serum after the precipitation of apoB containing lipoproteins with phosphotungstic acid and Mg. LDL was evaluated by determining the difference between total cholesterol, HDL and triglycerides (Friedewald *et al.*, 1972). Testosterone in serum was determined using the direct immunoenzymatic assay (Elisa method) as described by Sood (2006). All the determinations were performed with a biochemical autoanalyzer.

Statistical studies

The statistical analyses were performed with the Statgraphics Plus version 5.0 software, using one-way ANOVA with the statistical significance set at the probability lower than 0.05 levels. Post-hoc analysis of the ANOVA was made using the Duncan test for multiple comparisons. The results are expressed as the mean ± S.D.

Results

Body and organ weights, water and food intakes

The water and food intakes, organs relative weight, and weights of animals at the initiation and after 20 days of the experimentation are shown in Table 1. Food and water intakes statistically increased ($p < 0.05$) in the test groups compared with the control.

The greatest values were observed in the animals physically trained and fed the experimental diet containing SASF. In contrast, final body weight significantly decreased ($p < 0.05$) in the test-groups in comparison to the control; with the lowest body weight noticed in the animal's rats trained and fed an experimental diet containing SASF. A similar tendency has been observed for the relative weights of the liver (test 1 and test 2), kidney and heart; while there was no significant difference in the weight of the testis between the test-groups and control.

Table 1. Experimental water and food intakes, body weight and the relative weight of organs.

Parameters	Control	Test 1	Test 2	Test 3
Food intake ($g.rat^{-1}.day^{-1}$)	8.9 ± 0.6	14.5 ± 1.2*	13.3 ± 0.9*	11.7 ± 1.4*
Water intake ($mL.rat^{-1}.day^{-1}$)	15.2 ± 1.3	28.6 ± 6.7**	24.4 ± 3.9*	21.8 ± 4.3*
Initial body weight (g)	169. 3 ± 5.3	164.4 ± 3.9	167.5 ± 7.8	168.2 ± 4.7
Final body weight (g)	198.5 ± 12.3	168.7 ± 9.5**	172.1 ± 8.6**	181.3 ± 6.3*
Liver weight ($g.100\ g^{-1}$ BW[a])	3.85 ± 0.38	2.79 ± 0.24*	3.13 ± 0.42*	3.71 ± 0.27
Kidney weight ($g.100\ g^{-1}$ BW)	0.93 ± 0.06	0.62 ± 0.01*	0.68 ± 0.04*	0.86 ± 0.03*
Heart weight ($g.100\ g^{-1}$ BW)	0.26 ± 0.07	0.41 ± 0.04*	0.35 ± 0.04*	0.30 ± 0.02*
Testis weight ($g.100\ g^{-1}$ BW)	1.1 ± 0. 0	1.2 ± 0.1	1.3 ± 0.1	1.2 ± 0.1

Control: animals fed normal diet. Test 1: rats fed on experimental diet + SASF, and submitted to physical activity. Test 2: rats fed experimental diet, and submitted to physical activity. Test 3: rats fed experimental diet + SASF.

Values are expressed as mean ± SD of six (06) animals over 20 days of experimentation

[a] BW: body weight

*** Significantly different (p < 0.01) compared with the control*

** Significantly different (p < 0.05) compared with the control.*

Weight of the abdominal wall

The weight of the abdominal wall of animals after 20 days of experimentation is presented in Fig. 1. The results revealed that there was no significant difference in weight between the groups of animals physically trained, regardless of the quantity or quality of diet intake, as well as water intake. Furthermore, it significantly diminished ($p < 0.05$) in the groups of animals trained in comparison to the control and those which fed on an experimental diet containing SASF. There was a tendency to decrease the abdominal wall weight in the rats (test 3) fed an experimental diet containing SASF compared with the control. However, the difference in the weight of the abdominal wall between control (group 1) and test 3 (group 4) was not significant.

Biomarkers of metabolic syndrome

The biomarkers of metabolic syndrome such as plasma concentrations of total cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides and glucose after 20 days of rat experimentation are shown in Table 2. HDL-cholesterol and triglycerides in blood had a decreasing tendency in rats trained (test 2), but there was no statistical difference compared with the control.

Table 2. Plasma concentrations of glucose, total cholesterol, LDL-cholesterol, HDL-cholesterol and triglycerides after 20 days of experimentation.

Parameters ($mg.dL^{-1}$)	Control	Test 1	Test 2	Test 3
Total cholesterol	79.3 ± 2.7	59.8 ± 5.6*	65.4 ± 4.8*	63.1 ± 3.9*
LDL-cholesterol	27.6 ± 5.2	12.9 ± 3.7*	14.6 ± 2.9*	16.5 ± 2.5*
HDL-cholesterol	44.7 ± 2.8	62.6 ± 3.7*	41.7 ± 1.9	52.8 ± 4.1*
Triglycerides	134.5 ± 9.6	88.9 ± 6.3*	121.6 ± 7.2	93.2 ± 11.2*
Glucose	98.5 ± 2.4	82.1 ± 1.9*	86.4 ± 1.7*	87.2 ± 3.1*

Control: animals fed on experimental diet. Test 1: rats fed experimental diet + SASF, and submitted to physical activity. Test 2: rats fed on experimental diet and submitted to physical activity. Test 3: rats fed on experimental diet + SASF.

** Significantly different ($p < 0.05$) compared with the control. Values are expressed as mean ± SD of six (06) animals.*

The levels of total cholesterol, LDL-cholesterol, triglycerides and glucose significantly decreased in the animals fed an experimental diet containing SASF and/or trained (test 1 and 3) in comparison to the control ($p < 0.05$). While HDL-cholesterol statistically increased in these rats ($p < 0.05$). The greatest value of HDL-cholesterol was noted in the animals trained and fed on an experimental diet containing SASF. While the lowest values were observed in the same group of animals in terms of total cholesterol, LDL-cholesterol and glucose. The animals of the test1-group exhibited the lowest levels of total cholesterol, LDL-cholesterol, triglycerides and glucose, and the greatest value of HDL-cholesterol.

However, the differences in the biomarkers of metabolic syndrome between the test-groups of animals did not give statistical significance, excluding triglycerides and HDL-cholesterol in rats trained and fed experimental diet.

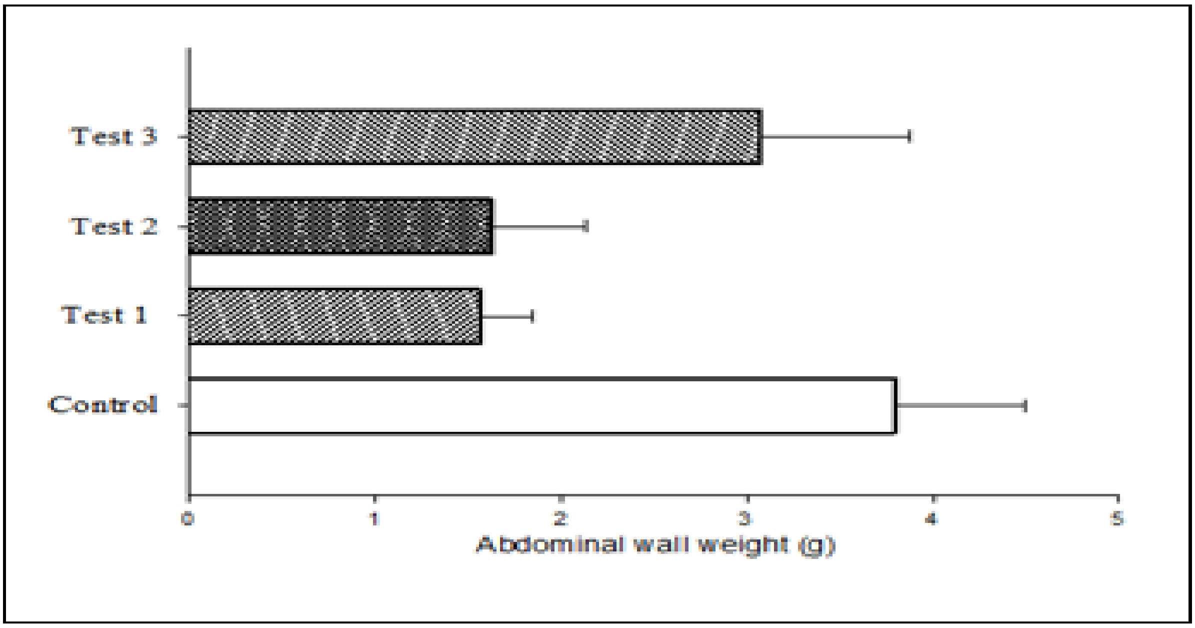

Fig. 1. The weight of abdominal wall in rats after 20 days of experimentation.

Control: animals fed normal diet. Test 1: rats fed on experimental diet + SASF, and submitted to physical activity.

Test 2: rats fed experimental diet, and submitted to physical activity. Test 3: rats fed experimental diet + SASF.

Values are expressed as mean ± SD of six (06) animals.

Plasma concentration of testosterone

The plasma concentration of testosterone after 20 days of rat experimentation is presented in Fig. 2. The level of testosterone was statistically higher in the rats trained or fed on an experimental diet containing SASF compared to the control ($p < 0.05$). The highest value of plasma testosterone had been noted in the rats trained and fed an experimental diet containing SASF. However, the training significantly increased the concentration of plasma testosterone in comparison to the feeding experimental diet containing SASF ($p < 0.05$).

Discussion

The body weights of animals were inversely correlated with water and food intakes. Endurance exercise can involve negative caloric balance (Hills *et al.*, 2011). In this study, energy spent due to physical training was higher than that intake through an experimental diet. Besides, the consumption of SASF could act by limiting the absorption of lipids and other sources of energy such as sugars and proteins.

The inhibitory effect on pancreatic lipase and amylase, chymotrypsin and trypsin by plant bioactive substances (polyphenols) has been proven (Etoundi *et al.*, 2010). SASF is rich in many bioactive compounds such as alkaloids, saponins, flavonoids and vitamin C (Sanchez-Mata *et al.*, 2010), and its glycaemic index is very low. This suggests that endurance exercise coupled with the consumption of SASF can be used as a means for global bodyweight management. However, this work showed that in rats, abdominal wall weight was directly related to the global bodyweight for the control group and test-groups trained, while rat abdominal weight was inversely correlated with global body weight in rats fed on only SASF.

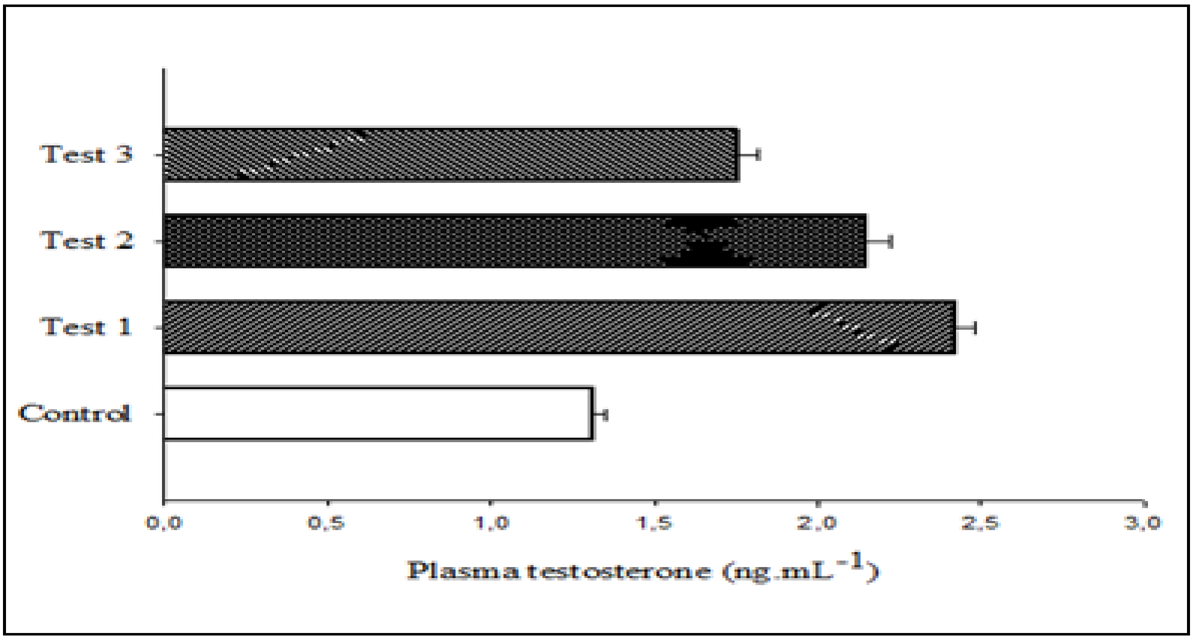

Fig. 2. Concentration of plasma testosterone after 20 days of experimentation.

Control: animals fed on normal diet. Test 1: rats fed on normal diet + SASF, and submitted to physical activity. Test 2: rats fed on normal diet, and submitted to physical activity. Test 3: rats fed normal diet + SASF. Values are expressed as mean ± SD of six (06) animals.

This observation indicates that endurance exercise can prevent the development of central obesity. In contrast, the diet containing SASF had an insignificant effect on this abdominal accumulation of fat. Perez-Gomez *et al.* (2013) demonstrated that endurance training decreased abdominal and body fat accumulation, and had effects on the blood lipid profile and hormonal changes. In this work, changes in cardiovascular health risk factors such as total cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides and glucose were directly associated with body weight. The body mass lost due to endurance training and SASF consumption induced the reduction in total cholesterol, triglycerides, LDL-cholesterol levels in the blood, as well as glycaemia, whilst the HDL-cholesterol increased. Recently, it has been proven that the elevation of HDL-cholesterol in the blood can prevent atherosclerosis and coronary heart diseases (Chapman, 2006). Contrary, a high level of LDL-cholesterol was associated with cardiovascular diseases (Halle *et al.*, 1999). The results of this study also show the correlations between abdominal wall weight and lipid profile. As for bodyweight, the decrease in abdominal wall weight was associated with the reduction in total cholesterol, triglycerides, LDL-cholesterol and glucose concentrations in blood. When the level in HDL-cholesterol increased in rat trained and/or fed a diet containing SASF (test 1 and 3), it decreased in animals submitted to the endurance training (test 2) only. This observation suggests that endurance training combined with a diet containing SASF might be mean to prevent obesity, cardiovascular diseases and other secondary chronic illness.

Testosterone is considered a key anabolic hormone with multiple physiological functions in the human body. In males, testosterone is mainly produced and secreted from the Leydig cells of the testes. The results of the present study suggest that testosterone concentration in blood was negatively correlated with relative organs, body and abdominal wall weights. The level of testosterone in blood was positively associated with HDL-cholesterol and negatively related to total cholesterol, triglycerides and LDL-cholesterol in rats trained and fed experimental diet containing SASF. These correlations between testosterone and heart health had been noted by other studies (Spark, 2007).

A diet containing SASF increased testosterone levels in the blood due to its bioactive substances such as saponins and flavonoids. This indicates that it might enhance body weight management, cardiovascular health, immune functions and fertility in males. On the other hand, SASF could be potentially used to induce muscle mass increasing, strength and improvement of fat catabolism.

Conclusion

Globally, results might suggest that the prevention of both obesity and metabolic syndrome is effective when animals are submitted to endurance exercises. Moreover, a diet containing SASF combined with physical training can give better outcomes. Therefore, this study shows that the promotion of durable health may well be linked to adapted physical activity combined with a diet containing raw vegetables with a low glycaemic index.

Acknowledgment

This study was supported by the Higher Institute of Health Profession, Yaoundé, Cameroon. The authors thank Professor Elisabeth NGO BUM and Doctor Jean OTELE MBEDE for their technical assistance.

Compliance - With Ethical Standards.

Conflict Of Interest – None.

Funding –None.

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