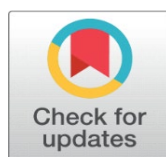
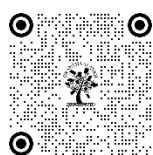


EFFECT OF SPIRULINA SUPPLEMENTATION WITH ASSOCIATED AEROBIC TRAINING PROGRAM ON BODY COMPOSITION OF OVERWEIGHT COLLEGE STUDENTS

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ABSTRACT

Objectives: The aim of the study was to observed independent and synergistic effect spirulina and aerobic training on body composition.

Methods: Total 40 sedentary male overweight college students were randomly selected and separated into four equal groups viz. Spirulina Supplementation, Spirulina supplementation with Aerobic Training, Aerobic Training and Control. Measuring criteria were Body fat percentage, Triglycerides and Body Mass Index. 12-week training protocol was introduced where 5gm Spirulina platensis tablets were fed every day for the supplementary and combined groups. Similarly, moderate intensity aerobic training was introduced 4 days per week for aerobic training and combined groups. One-way ANCOVA and Bonferroni post hoc comparisons were used to examine training effects within groups.

Results: Body fat percentage, Triglycerides and Body Mass Index showed significant difference at 0.05 level after introduced all the training protocol.

Conclusion: It was concluded from this study that all three experimental groups successfully reduced body composition parameters in overweight individuals.

Keywords: Spirulina, Aerobic Training, Body Composition, Body Fat Percentage, Triglycerides and Body Mass Index

1. INTRODUCTION

With the age of modernization and technological advancement, people's tendency to work has decreased, competition and population explosion have increased the stress. As a result, the younger generation is suffering from a new type of disease known as non-communicable disease or hypokinetic disorder. These disorders are of various types, but current research has focused on overweight and obesity. Now a days obesity or overweight was considered as a chronic disease resulting from an interaction between an individual's genetic predisposition to weight gain and environmental influences ⁽¹⁾. WHO defines overweight and obesity as “abnormal or excessive fat accumulation that presents a risk to health” ⁽²⁾. The WHO defines overweight as a BMI greater than or equal to 25 kg/m², while obesity is a BMI greater than or equal to 30 kg/m² ⁽²⁾. As per the WHO's data, the global prevalence of obesity almost tripled between 1975 and 2016, including low-income and middle-income categories ⁽³⁾. Based on the WHO Asia-Pacific guidelines, in NFHS-5 survey the overall weighted prevalence of overweight and obesity among male and female study participants was 44.02% and 41.16%, which was increased to 16.7% and 13.8% compare to the survey of NFHS – 4 ⁽²⁾.

In the current era, there is no such invention of drugs that can reduce overweight and obesity, the current researcher thinks, if there is, the people of this generation do not want to use drugs considering the bad effects. But some studies showed herbal and behavioural based treatment protocol were effective to control adiposity. From there Spirulina and Aerobic training one of most important supplements and exercise protocol which have some potentiality to control obesity and overweight according to various research article ^(4,5). Among the different species of this algae, *Spirulina platensis* (*Arthrospira platensis*) is the most common and available blue-green unicellular algae with nutraceutical, probiotic, antioxidant, anti-inflammatory, hypolipidemic, hypoglycaemic, antihypertensive, and immunomodulatory properties. Spirulina has been shown to be an efficient dietary supplement for weight control by reducing lipid peroxidation and adipose reserves, due to its excellent nutritional profile and the large amount of protein elements, phycocyanin, carotenoids, and all important amino acids ⁽⁶⁾.

Aerobic training is a powerful method for weight loss, and reduction of total body fat percentage. For controlling body composition parameter, exercise duration and intensity play a very vital role. Research studies showed that moderate aerobic exercise may improve risk factors for metabolic syndrome like body composition, insulin resistance. American College of Sports Medicine suggested that long-term moderate aerobic exercise for >150 or 200–300 min per week can significantly reduce body weight when the diet is not controlled ^(7,8).

Therefore, the main aim of this study was to observed independent and synergistic effect spirulina and aerobic training on body composition parameters such as Body fat percentage, Triglycerides and BMI. Along with this, the rate of improvement in the group was also observed.

2. METHODOLOGY

2.1. SUBJECTS

For the purpose of the study, total 40 sedentary male overweight (19 – 25 years) college students whose BMI ranged between 25 – 29.9 kg/m² were randomly selected from the two colleges of Purba Medinipur, West Bengal. All the subjects were randomly separated into four equal groups of 10 subjects each viz. group I Spirulina Supplementation Group (SG), group II Spirulina supplementation with Aerobic Training Group (SATG), group III Aerobic Training Group (ATG) group IV acted as Control Group (CG) who just followed the normal routine. Among 40 subjects 6 subjects (SG = 2, SATG = 2, AT = 2) did not take supplementation and did not even take part in training programme regularly due to lack of interest, injury and sickness and they were eliminated from the post-test data collection procedure. Finally, 32 subjects completed the entire treatment protocol viz. 8 subjects from SG, 8 subjects from SATG and 8 subjects from ATG group completed the supplementation and training protocol. All the subjects were checked by the physician and certified for training programme and written consent was taking from the subject. The participants were no history of infectious disease, no participation in regular sports activities, non-smoking, no use of medication or food supplements, no participation in another biomedical trial during the treatment, and no abuse of drugs or alcohol.

3. MEASURING CRITERIA AND TOOLS

3.1. PERSONAL DATA

Age was evaluated through the date of birth, weight and height were measured through well calibrated weighing machine and stadiometer with minimal cloth and without shoes.

3.2. BODY COMPOSITION

Body fat percentage (BF) measured through the Tanita Body Composition Analyser (Model no: DC-430MA; Accuracy grade: MDD - Class IIa) and Triglycerides (TG) was measured from blood serum by Bio – Chemistry Analyser through the method of GPO – PAP, end point Assay. Body Mass Index (BMI) was measured through the online BMI calculator (Centers for Disease Control and Prevention, 2022, July 21; National Heart, Lung, and Blood Institute on line BMI calculator).

3.3. TRAINING PROTOCOL

The study was carried out in the gymnasium and play ground of Panskura Banamali Colleges (Autonomous), Panskura, Purba Medinipur. The Aerobic Training protocol for training Group and Training with Spirulina

Supplementation Group conducted 70 min/session (Warm up – 10 min, Aerobic training – 50 min, Cooling down – 10 min), 4 days/week, for 12 weeks. The exercises for the treatment were chosen based on the results of pilot study and according to the guideline of ACSM 2011. The selected exercises were brisk walking, jogging, jumping jack and its variation, skipping with the intensity of 55 to 75 person of maximum heart rate, and repetition, recovery and set was planned according to the principle of progressivity and adjustability. The SG and SATG were fed 5gm spirulina tablet every day before lunch for three months (manufactured by SUNOVA Organic Spirulina Capsules). During the training phase, the control group was asked to follow their normal daily routine work and not get involved in any type of exhaustive activity.

3.4. STATISTICAL ANALYSIS

All the statistical analyses were performed by using SPSS, version 25.0 on windows 10.0 and significant level considered 0.05. At first the mean and SD was computed for simpler interpretation of the data. Shapiro-Wilk test and Kolmogorov – Smirnov test was computed to determine the sample data has been drawn from normally distributed population or not, and Levine's Test was computed for homogeneity test to determine the equal distribution of single categorical variables of the groups and found satisfactory results. One Way Analysis of Covariance (ANCOVA) was used to determine differences among the groups. Bonferroni post hoc comparison was computed to compare the effects of 12- week training program on each group. Pearson product moment correlation to find out the relation between total cholesterol and body fat percentage and BMI.

4. RESULTS

The result of this study was divided in three section first section interprets the normality and homogeneity of data, second section showed the characteristics of the data and last section find out the effect of treatment on the selected body composition variables. 80% of subjects were completed the guided training protocol and remaining 20% subjects were not showing any interest.

Table 1 Descriptive characteristics of all variables

Variables	Group	Mean	SD
Age (Yr.)	All Gr.	22.16	0.33
Height (cm)	All Gr.	169.88	0.39
Weight (kg)	All Gr.	79.31	1.02
BF Pre (%)	CG	24.92	±1.15
	SG	25.00	±1.26
	ATG	24.20	±0.86
	SATG	24.76	±0.61
BF Post (%)	CG	25.25	±1.16
	SG	24.41	±1.19
	ATG	23.26	±1.28
	SATG	22.45	±0.77
TG Pre (mg/dl)	CG	111.69	±9.18
	SG	105.78	±17.71
	ATG	107.89	±13.37
	SATG	124.19	±11.93
TG Post (mg/dl)	CG	111.73	±9.117
	SG	104.79	±17.70
	ATG	106.56	±13.65
	SATG	122.50	±11.97

BMI Pre (kg/m ²)	CG	27.24	±1.04
	SG	27.64	±1.06
	ATG	27.71	±1.40
	SATG	27.15	±1.14
BMI Post(kg/m ²)	CG	27.41	±1.08
	SG	27.19	±0.95
	ATG	27.14	±1.57
	SATG	26.40	±1.10

The normality and homogeneity of the data were calculated for selection further inferential statistics. In 91% cases data showed normality and homogeneity remaining 9% data didn't follow the normality and homogeneity pattern. Since most of the data were normal and homogeneous that's why the current researchers use parametric inferential statistics for further calculations. The descriptive characteristics (Table 1) were calculated through mean and standard deviation. From there present investigator aware about the condition of the subject in both pre and posttest time. One way ANCOVA (Table 2) was performed to find out the effect of training after adjusting the post-test data. From this result it was observed that BMI, BF and TG showed highly significant difference among the group at 0.05 level, and F value between the group (Post – test data) was (df = 3,27) 44.36, 20.69 and 17.92. From the Bonferroni correction it was observed that all the experimental group showed significant difference in respect of control group at 0.05 level. But in case inter-treatment group comparison, SATG group showed most significant results at 0.05 level in terms of BF and TG. In case of BF, SATG group showed significant difference at 0.05 level in terms of SG & AG. In case of TG,

STAG group showed significance difference at 0.05 level in terms of SG. But in case of BMI inter group didn't showing any significance difference at any level.

Table 2 One-way ANCOVA and Bonferroni Post hoc comparison between group

Variables	F (df = 3,27)	P E ²	Bonferroni Post hoc comparison					
			CG			SG		AG
			SG	AG	SATG	AG	SATG	SATG
BF	44.36**	0.83	0.91 *	1.26 *	2.64 *	0.34	1.72 *	1.38 *
TG	20.69**	0.70	1.01 *	1.35 *	1.79 *	0.34	0.78 *	0.44
BMI	17.92**	0.67	0.63 *	0.75 *	0.93 *	0.13	0.30	0.18

5. DISCUSSION

Body Fat Percentage was a crucial indicator of an individual's overall health and fitness level. Healthy body fat percentage plays a vital role in determining the risk of chronic health conditions ⁽⁹⁾. The one way ANCOVA results of Body Fat percentage showed highly significant difference between treatment and control group. The effect size was 0.83 which was very large, which suggest that 83% of variance in Body Fat percentage can be explained by spirulina supplementation after accounting the baseline difference. All the training group showed successful improvement in respect control group. In terms of adjusted post-test mean difference, spirulina treatment showed fat percentage reduction of 3.65% compared to the control group. 5.02% body fat percentage decreased during aerobic training and 10.52% body fat percentage decreased during combined training compared to control group. From this result it was observed that combined training was more effective than Spirulina and Aerobic training group. Also, inter-experimental Bonferroni comparison showed that among the three treatment groups, the rate of improvement in the combined group was significantly higher. The combined group lost 7.14% more body fat compared to the spirulina group and 5.80% more fat loss than the aerobic training group.

Spirulina, was nutrient rich blue-green algae, its high protein content, vitamins, minerals, and antioxidants was very helpful for weight management and maintain lipid profile. High protein intake can increase satiety, reduce hunger, and consequently lower overall caloric intake also it has a higher thermic effect compared to fats and carbohydrates, meaning more energy is expended during its digestion and metabolism, which can contribute to weight loss 10–13. Its antioxidants properties, such as phycocyanin, beta-carotene and vitamin E, which help to fight against oxidative stress and inflammation associated with obesity and metabolic disorders. By reducing oxidative stress and inflammation, spirulina can improve metabolic health and increase fat oxidation, thereby reducing body fat percentage ^(10,14). Different studies shown that spirulina can improve lipid profiles by reducing levels of total cholesterol, low-density lipoprotein, and triglycerides while increasing high-density lipoprotein which improved lipid metabolism through the help of Gamma Linolenic Acid and enhance the body's ability to utilize fats for energy, thus reducing body fat stores ^(11,15,16). Another study showed that spirulina enhance insulin sensitivity, which can lead to better glucose metabolism and reduced fat storage ⁽¹⁷⁾.

According to present researcher aerobic exercise requires more energy demand, which leads to higher caloric burn through the processes of beta oxidation which help to reduce body fat percentage. Supported research document was also mentioned that continuous aerobic activity promotes the use of fat as a fuel source, especially at moderate intensities where fat oxidation is maximized ⁽¹⁸⁾. Another research paper which supported the current research paper and concluded that regular aerobic exercise increases the body's muscle mass and improves metabolic functions, leading to a higher BMR. An elevated BMR means that the body continues to burn more calories even after exercise, which aids in reducing body fat over time ⁽¹⁹⁾. Several research studies also mentioned that aerobic training induces catecholamines which stimulate fat breakdown or lipolysis and the release of fatty acids from adipose tissue and also lower cortisol levels, a hormone associated with fat accumulation, particularly around the abdominal area ^(20,21).

The synergistic effects of increased caloric expenditure, enhanced metabolic rate, improved insulin sensitivity, antioxidant and anti-inflammatory properties, and favourable hormonal changes contribute to this substantial reduction. These findings support the use of combined aerobic training and spirulina supplementation as a most effective strategy for reducing body fat and improving overall body composition than other methods.

Triglycerides are a type of fat, called lipid. it is the most common type of fat in human body. Triglycerides come from foods and excess energy consumption. In emergency situation when body needs energy, triglycerides release energy through beta oxidation processes. Normal level of triglycerides (150 mg/dl) are always good for health but high triglyceride levels (> 150 mg/dl) increase the fat deposition in the body and also increase the chances of other chronic disorders^{22,23}. The high F-value of TG indicates substantial differences among the groups. Moreover, the partial eta squared value suggests a large effect size, indicating that treatment protocols account for a significant proportion of the variance in triglyceride levels. In terms of adjusted post-test mean, Triglyceride level was reduced 0.90% by spirulina treatment compare to the control group. After aerobic training it was decreased 1.20 % and after combined training it was reached at 1.59% compare to control group. As with body fat percentage, it was also clear that combined training significantly affects Triglyceride level. Similarly, to Body fat percentage it was also observed from inter experimental comparison that the rate of improvement of combined training group was higher than Supplementation group (0.70%).

This study demonstrates that spirulina supplementation significantly reduces triglyceride levels compared to a control group over a 12-week period. The several suggested mechanisms were involved behind this reduction include regulation of lipid metabolism, antioxidant properties, improved insulin sensitivity, increased lipoprotein lipase activity, and reduced hepatic triglyceride production. By now lipid metabolism, antioxidant properties, improved insulin sensitivity were already discussed in detail in the body fat section with proper supported mechanism and references. Previous researcher showed that Spirulina supplementation may increase the activity of lipoprotein lipase, an enzyme crucial for the hydrolysis of triglycerides in lipoproteins. Enhanced lipoprotein lipase activity facilitates the breakdown of triglycerides into free fatty acids and glycerol, thereby lowering circulating triglyceride levels ⁽²⁴⁾. It was also believed by the researcher that Spirulina may also directly affect the liver's production of triglycerides. The liver was the primary site for triglyceride synthesis, and spirulina's bioactive compounds can modulate hepatic enzymes involved in lipid metabolism, reducing the liver's output of triglycerides ⁽²⁵⁾.

A group of researchers thought that aerobic training, like spirulina, increased lipoprotein lipase activity. Later studies showed that moderate intensity aerobic training leads to upregulation of lipoprotein lipase gene expression by activating nuclear receptors and energy sensors such as Peroxisome Proliferator-Activated Receptor Gamma & Activated Protein Kinase leading to lipoprotein lipase enzyme increases secretion ^(26–28). Another underlining mechanism to reduce

the triglyceride level through Aerobic training was increased fat oxidation. The increased fat oxidative capacity through training which enhances the body's ability to utilize fat as fuel during exercise and also reduce triglyceride ^(18,29,30).

The combined intervention of aerobic training and spirulina supplementation offers a potent approach to managing triglyceride levels effectively. The distinct mechanisms involved in each component contribute to an enhanced lipid profile, with both exercise and spirulina promoting increased clearance of triglycerides, leading to significant health benefits for individuals ⁽³¹⁾.

BMI is a useful measure of overweight and obesity. BMI is an ideal predictor of body fat and related health risk. F value showed significant changes in BMI after implementing the all three training protocols. The partial eta squared value was 0.67 which suggests that the effect size was large, indicating that all treatment protocols account for 67% variance in BMI levels. In terms of adjusted post-test mean, 2.26% BMI value was reduced by spirulina treatment compare to the control group. After aerobic training it was decreased 2.72 % and after combined training it was reached at 3.35% compare to control group. As with body fat percentage & triglyceride level it was also clear that combined training significantly affects BMI value. As there were no differences in inter-treatment group comparisons in terms of rate of improvement, it was assumed that the treatment protocols affected BMI equally.

A review study by Bhatt et al showed that different researchers working on obese subjects measured BMI and weight loss. For example, Yousefi and other researchers were able to significantly reduce weight, BMI, triglyceride, total cholesterol, waist circumference by consuming 2 grams of spirulina supplement per day for 12 weeks ⁽³²⁻³⁵⁾. Similarly, another study showed that a 1 g per day spirulina dose for 12 weeks was able to reduce BMI and TC sufficiently, which definitely supports the current study because the current researcher's dose of spirulina supplement was higher ⁽³⁶⁾. Spirulina-induced BMI reduction was thought to be due to decreased infiltration of visceral fat into macrophages, inhibition of hepatic fat accumulation, and significant enhancement of leptin signalling in the arcuate nucleus of the brain, which directly affects BMI ^(32,37,38).

In terms of aerobic training, the present study found the same results as the studies mentioned below, viz Ross & Janssen reviewed on exercise induced weight loss and that short term training which was less than 16 weeks were successfully reduced the body weight and fat which were directly related with reduction of BMI ⁽³⁹⁾. Mohammadi and other researcher followed the same training protocol that the present researcher followed and found significant reduction of weight, BMI, fat mass compare to other training group. This study suggested that median intensity aerobic training protocol was very effective for reduced body composition parameter for overweight to obese people ⁽⁴⁰⁾. Marandi et al., showed same result after 10 weeks of light and moderate aerobic training programme where significant decrease in weight, BMI, fat percentage, waist hip ratio and triglyceride level. This study directly supports the present study ^(41,42).

Reviewing the data for the previous two variables, it is understood that since combined training has the greatest effect on fat and triglycerides, the change in BMI will naturally be proportional to the greatest. In that case, the present researcher thinks that the above mechanism and supported research papers are sufficient in serving the argument.

6. CONCLUSION

It was concluded from this study that all three experimental groups successfully reduced body composition parameters in overweight individuals. Among these three experimental groups, the combined group especially affected body fat, triglycerides and BMI. Therefore, the present researcher believes that these training protocols will be suitable for control of body composition parameters in overweight and obese population.

CONFLICT OF INTERESTS

None.

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