Effect of *Spirulina maxima* on Postprandial Lipemia in Young Runners: A Preliminary Report

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ABSTRACT Trained people exhibit low plasma concentrations of triacylglycerols in both fasting and postprandial states. Exercise practice is commonly believed to improve postprandial lipemia. In addition, elevated postprandial lipemia is an indicator of poor lipid clearance, and it has been associated with atherosclerosis, insulin resistance, and obesity. *Spirulina maxima* is an edible microorganism with a high nutritional value. When it is consumed, beneficial properties to health have been demonstrated, such as hypolipemic and antihypertensive properties in human beings. This work evaluates the effects of orally administered *S. maxima* on postprandial lipemia in a young Mexican sporting population after 15 days of consumption, as a possible alternative treatment to improve their lipid clearance. Forty-one runners (10–26 years old; 21 men and 20 women) volunteered to participate in the study. All of them were physically active for at least 1 year before the study and were not undergoing training during the study. The subjects consumed 5 g of *Spirulina* during 15 days. Before and after the treatment with *Spirulina*, they consumed (12 h fasting) a standardized meal with high fat content (53.2% total calories). Postprandial lipemia was measured at 1.5, 3, and 4.5 h after the fatty meal. Fasting plasma triacylglycerol (TAG) concentrations were lower after *Spirulina* treatment than before treatment. In addition, the postprandial area under the curve of TAG concentrations was lower after the treatment with *Spirulina*. Sixty-two percent of the youngest runners (10–16 years) studied exhibited the best response to the treatment. Orally administered *S. maxima* decreased postprandial lipemia in sporting teenagers. The youngest people were the most responsive to the beneficial effects of *Spirulina* on postprandial lipemia.

KEY WORDS: ● area under curve ● exercise ● nutrition ● triacylglycerols

INTRODUCTION

In recent years, several studies have been performed in an attempt to support the hypothesis that accumulated physical activity has health benefits. The findings of these studies suggested that persistent physical activity is effective in lowering postprandial triacylglycerol (TAG) concentrations.1–3 Other authors have proposed that fasting plasma TAG concentration is the best predictor of postprandial lipemia.4,5

Exercise response and lipid metabolism are influenced by age and sex. These could be explained by hormonal changes, especially growth hormone and the sexual hormones, testosterone and estrogens. These hormones have an important effect on the muscular and adipose tissues and lipid transport.6–10 Other hormones that are directly involved in lipid changes observed during exercise are insulin, as well as the adrenaline/noradrenaline (A/NA) ratio, because during exercise, insulin concentration diminishes while catecholamine concentration increases, causing activation of lipoprotein lipase (LPL) and hormone-sensitive lipase.11

On the other hand, postprandial lipemia is considered to be associated with the presence or development of coronary artery disease.4 In fact, elevated postprandial hypertriacylglycerolemia indicates poor lipid clearance and is associated with atherosclerosis, insulin resistance, an elevation in cholesterol associated with low-density lipoprotein (C-LDL) concentration, a decrease in cholesterol associated with high-density lipoprotein (C-HDL) concentration, and obesity.4,12

Many studies13,14 have shown that acute and chronic exercise mitigates the elevation of plasma TAG concentration after a fatty meal. Most of these studies have employed test meals containing exceedingly high amounts of fat (at least 10 g/kg body mass or more than 60% of total energy). Other studies recently examined the effect of exercise on lipemia after a meal of high-fat content, which is closer to that of the typical Western diet (35% total energy) and found a
significant reduction in postprandial lipemia.\textsuperscript{15} It has been proposed that delayed and sustained activation of LPL in the muscular capillaries is due to exercise, and this accelerates the clearance of circulating TAG in the postprandial state.\textsuperscript{16,17}

Despite the beneficial effects of exercise, its practice in our country is limited. This agrees with a study conducted by Dumith \textit{et al.},\textsuperscript{18} who reported that the overall worldwide prevalence of physical inactivity was of 21.4\%, being higher in women than in men. This study showed that Mauritania is the most physically inactive country with a mean prevalence of 62\%. On the other hand, we face the problem of a fat-rich and protein-poor diet; both these factors affect exercise performance. A study conducted by Ortiz-Hernández and Gómez-Tello\textsuperscript{19} showed that in 7218 Mexican adolescents, two-thirds did not consume fruit and vegetables, one-third consumed soft sweet drinks, and one-fifth consumed salty snacks. In a study by Rodríguez-Oliveros \textit{et al.},\textsuperscript{20} it was shown that there are many barriers in childhood that have to be overcome to practice physical activity, which included the influence of young family members to play video games, parental time constraints, street safety, low access to sports facilities, unhealthy food preparation practices, and the consumption of junk food or bad food. However, it is possible to counteract the influence of bad food on health by using some natural products, such as \textit{Spirulina}, which has been studied as food supplements for subjects in training.

\textit{Spirulina maxima} is a filamentous unicellular cyanobacterium belonging to the Oscillatoraceae family that usually grows in the alkaline waters of Africa, Asia, and North and South America.\textsuperscript{21} \textit{Spirulina} has been used as a food additive due to its high protein content, as well as its essential nutrients such as carotenoids, vitamins, and minerals.\textsuperscript{22} In addition, previous studies have demonstrated that \textit{Spirulina} (rich in iron and vitamins) prevents anemia, inhibits herpes simplex infection, decreases HIV replication velocity, increases antibody production, and has hypoglycemic, hypolipemic, and antihypertensive properties in experimental models and humans.\textsuperscript{23,24} as well as hepatoprotective properties through decreasing liver lipid profile and lipoperoxidation.\textsuperscript{25} In fact Kalafati \textit{et al.}\textsuperscript{26} recently studied the effect of 6 g per day of \textit{Spirulina} on nine moderately trained men. They measured exercise performance and some antioxidant enzymes after placebo and \textit{Spirulina} supplementation, and found that the \textit{Spirulina} supplement induced a significant increase in exercise performance, fat oxidation, and reduced glutathione concentration, and attenuated the increase of exercise-induced lipid peroxidation.

Furthermore, Lu \textit{et al.}\textsuperscript{27} demonstrated that \textit{Spirulina platensis} prevented skeletal muscle damage in eight untrained subjects progressively submitted to treadmill exercise according to Bruce protocol, suggesting that this could explain the postponement of exhaustion time among athletes fed on \textit{S. platensis}, similar to those of Nagpur, India.

The purpose of this study was to assess the effects of orally administered \textit{S. maxima} on postprandial lipemia in a young Mexican sporting population after 15 days of treatment.

\\begin{table}[h]
\centering
\caption{Composition of Diet for Postprandial Lipemia}
\begin{tabular}{lcccc}
\hline
\textbf{Meal} & \textbf{Amount} & \textbf{Protein} & \textbf{Lipids} & \textbf{Carbohydrates} & \textbf{Energy} \\
 & (g) & (g) & (g) & (g) & (kcal) \\
\hline
Pork rinds & 20 & 11 & 9 & 0 & 125 \\
Muffin & 125 & 7.4 & 32.8 & 61.2 & 572 \\
Yoghurt & 250 & 5.76 & 6.5 & 31.7 & 211.3 \\
Small pork sausage & 58 & 5.4 & 14.8 & 0.7 & 160 \\
\textbf{Total} & \textbf{453} & \textbf{29.5} & \textbf{63.1} & \textbf{93.6} & \textbf{1068.3} \\
\hline
\end{tabular}
\end{table}
\textsuperscript{*}Each one of these products represents a normal typical Mexican collation.
control program adherence in young populations. Furthermore, it has been demonstrated that detraining effects could occur within 2 weeks or more after stopping the training.9

Participants were divided (on the basis of the principal changes during growth) into three age groups: 10–12 years (n = 9 women and n = 3 men), 13–16 years (n = 6 women and n = 8 men), and 17–26 years of age (n = 5 women and n = 10 men).

Statistical analysis

Statistical analyses were performed using GraphPad Prism software, version 4. We compared the means between groups using an unpaired t-test. In order to evaluate changes in lipemia, we used area under curve (AUC) of the TAG concentrations versus the time calculated starting from the value just before the consumption of the meal and using the trapezoidal rule. Results were represented as a percentage of ΔAUC of each group of participants with and without treatment. We also used the Student t-test to evaluate the differences in TC and TAG concentrations between participants with and without Spirulina treatment.

RESULTS

The study initially included 41 volunteers, but only 29 participants concluded the tests. No differences in basal characteristics between men and women were observed, according to age and sex (data not shown), indicating a homogenous group. The fat meal used for postprandial lipemia consisted of a high amount of lipids (34%) and adequate carbohydrate (50%) and protein (16%) content. We observed that the most important support of energy in this diet was derived from lipids (53.2%), then carbohydrates (35.1%), and, finally, proteins (11.04%). These kinds of products are usually consumed in the urban Mexican population (Table 1).

The effects of Spirulina on TAG, TC, and C-HDL fasting concentrations are depicted in Table 2. Differences in neither TC nor C-HDL were observed when comparing concentrations before and after treatment; but lower values of fasting TAG concentrations were found after Spirulina treatment. Figure 1 represents the percentage of change in plasma TAG both before and after Spirulina treatment in all participants at 1.5, 3, and 4.5 h after the fat meal. This figure shows that 18 out of the 29 final participants had reduced lipemia at the three times (prevalence 62%) and that the most important reduction was observed at 4.5 h with 42%.

Then, we analyzed the effects of Spirulina according to age, comparing the percentage of changes observed in AUC. We noted that the main decrease occurred in the youngest group with 30%, and similarly in the group of participants between 13 and 16 years of age with 7%. However, this decrease is not evident in the oldest group, Figure 2.

Before exercise, fasting lactate concentration was 2.25–1.19 without Spirulina versus 1.70–0.58 with Spirulina. After exercise, fasting lactate concentration was 15.53–4.15 without Spirulina versus 12.78–6.25 with Spirulina. Despite the trend to lower lactate concentration with Spirulina, the differences were not significant.

DISCUSSION

A few studies have shown that exercise performed 1 day, or even 1 h, before the fat meal effectively diminishes postprandial lipemia. These studies demonstrate this effect in the form of changes in AUC.3,12,28–30 However, Zhang

Table 2. Spirulina Effects on Fasting Plasma Lipids

<table>
<thead>
<tr>
<th>Total subjects</th>
<th>Before treatment</th>
<th>After treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAG (mg/dL)</td>
<td>71.47±5.8</td>
<td>57.06±24*</td>
</tr>
<tr>
<td>TC (mg/dL)</td>
<td>154.4±28.8</td>
<td>148.7±25.4</td>
</tr>
<tr>
<td>HDL-C (mg/dL)</td>
<td>56.04±10.8</td>
<td>51.4±9.4</td>
</tr>
</tbody>
</table>

TAG, triacylglycerols; TC, total cholesterol; HDL-C, cholesterol associated to high density lipoproteins.

*P=.04, n=29.

FIG. 1. Effects of Spirulina on postprandial lipemia. Results are expressed as a percentage of change in plasma triacylglycerol, before and after Spirulina treatment, at three times selected for postprandial analyses (1.5, 3, and 4.5 h, n = 29).

FIG. 2. Effects of Spirulina on lipemia according to age group. Results are expressed as a percentage of change in area under curve (AUC) values of postprandial lipemia in the three age groups (10–12 years, n = 12; 13–16 years, n = 14; 17–26 years, n = 15).
et al.," observed this effect when exercise was performed before but not after the meal. These studies have used high-fat test meals. In our study, participants were asked to suspend exercise practice 36 h both before treatment and during the study, in order to view the changes induced by treatment with Spirulina in physically active subjects.

Other studies have determined that Spirulina increases exercise performance, possibly through an increase in β-oxidation pathway rate and increases in reduced glutathione levels. Furthermore, it is already known that exercise increases LPL activity, and in our study, we propose that changes seen in lipemia could be associated with an increase in LPL activity, previously increased by the effect of exercise. On the other hand, we have seen that S. maxima is a good food source with a high nutritional value and has hypolipidemic and anti-inflammatory activities, factors which have a positive impact on exercise performance.

In this study, we have demonstrated that Spirulina has an important effect as a hypotriacylglycerolemic product. Furthermore, we observed no changes in C-HDL levels and an important effect as a hypotriacylglycerolemic product. Blood lactate is a natural metabolite that is produced by glycolysis and is accumulated during exercise, according to the intensity and duration of physical activity, and it is also associated with a decrease in buffer capacity. Thus, maintaining a lower lactate concentration during exercise improves aerobic capacity. Trained individuals with a high-endurance capacity display lower blood lactate levels at a given cycling power output testing or running velocity than a sedentary individual. In other words, trained individuals will be able to work at a higher absolute intensity. Before treatment (without Spirulina), lactate concentration was higher at the end of the exercise than in those with Spirulina, which probably means that Spirulina either improves aerobic capacity or decreases the activity of lactate dehydrogenase. Unfortunately, we were unable to find significant differences.

The effects on lipids in men and women are different, but in this study, there were no differences, probably because it was a trained small population; however, this is a preliminary report that provides us significant information for further studies.

CONCLUSION

Spirulina diminishes postprandial lipemia after a high-fat meal in young athletes, especially between 10 and 16 years of age. We observed this effect since 1.5 h, although at 3–4.5 h, the decrease is higher. This effect was observed despite a short detraining period.

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AUTHOR DISCLOSURE STATEMENT

No competing financial interests exist.

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