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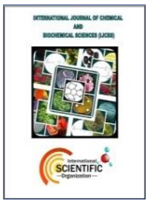

The satiating effect of polyunsaturated fatty acids consumption and its impact on the metabolic health in albino rats

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Abstract

Understanding and improving metabolic health can prevent chronic diseases such as diabetes, obesity, and cardiovascular diseases. This includes lifestyle modification, dietary recommendations, and medical treatments. The current study aimed to explore the satiating effect of polyunsaturated fatty acids (PUFAs) in the diet and its impact on metabolic functions. 30 adult male albino rats were divided into 3 groups: The control group, the high-neutral fat diet (HFD) group, and the polyunsaturated fatty acids (PUFAs) group. Food intake and body weight were followed up. Serum levels of glucose, insulin, and leptin were estimated. Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) was also calculated. The HFD group showed a significantly elevated food intake, body weight, serum glucose, insulin, leptin and HOMA-IR compared to other groups. PUFAs group showed a significant improvement regarding all parameters. Diets rich in PUFAs have a satiating effect which may contribute to the improvement of metabolic health.

Keywords: PUFAs, HOMA-IR, satiety, leptin, metabolic health.

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1. Introduction

High-fat diets can influence food intake in different ways depending on various factors, including the type of fats consumed and individual responses. In some cases, high-fat diets may lead to an increased food intake due to reduced satiety signals and changes in appetite-regulating hormones. However, certain healthy fats may have a satiating effect that potentially reduces the overall food consumption [1]. Food intake plays a crucial role in metabolic health. High caloric intake can contribute to metabolic disorders like obesity and insulin resistance. On the other hand, insufficient food intake or poor nutritional quality may lead to a negative impact on the metabolism. Thus, maintaining a healthy and balanced diet is essential for promoting and preserving metabolic health [2]. Improving metabolic health is crucial for enhancing overall well-being and quality of life. The normal metabolic function involves the utilization and regulation of energy within the body. This contributes to better insulin sensitivity, reducing the risk of developing type II diabetes. Accordingly, balanced diets may prevent rapid spikes in blood glucose levels, reducing the risk of insulin resistance and type II diabetes [3]. Diets rich in polyunsaturated fatty acids (PUFAs) offer various health benefits. PUFAs, including omega-3 and omega-6 fatty acids, are essential fats that are known to have positive effects on cardiovascular health, brain function, and inflammation regulation. Incorporating PUFAs into the diet may contribute to improving the lipid profile, reducing inflammation, and enhancing overall metabolic health [4]. The current study aimed to explore the impact of consumption of a diet rich in PUFAs on the level of satiety and its influence on metabolic functions.

2. Materials and methods

2.1. Animals

Thirty adult male albino rats of local strain weighing between 180-200 grams were used in the experiment. Rats were kept at room temperature with natural light/dark cycles and left to acclimatize to the environment before the start of the experiment. Initial food intake and body weight were reported. The principles of laboratory animal care were followed according to the rules of the Institutional Animal Care and Use Committee (IACUC), and the experimental procedures were conducted in the Faculty of Medicine, Minia University, Egypt.

2.2. Experimental groups

The rats were randomly divided into 3 groups

(10 rats each) to receive different types of diets for 2 months as follows:

2.2.1 Control group

The rats of this group were fed with a standard commercial rat chow diet (SD). It consists of 21% protein, 3% fat, 46% carbohydrates and 30% other constituents including fibers, vitamins, and minerals). It provided about 3035 Kcal/kg diet. It was purchased from El-Qahera Company (Minia, Egypt).

2.2.2. High-neutral fat diet (HFD) group

The rats of this group received a high-neutral fat diet rich in long chain saturated fatty acids. It consists of 40% fat mainly butter, 30% carbohydrate, 20% protein and 10% fibers and vitamins. It provided about 5995 Kcal/kg diet [5].

2.2.3. Polyunsaturated fatty acids (PUFAs) group

The rats of this group received a diet enriched with omega-3 (ω−3) fatty acids. It was prepared manually by mixing 55% SD with 29% fat, 7% milk, 6% casein and 3% vitamins. The daily oral dose of ω−3 fatty acid given was 500 mg/kg. It was withdrawn by puncturing the capsule {capsule; 1000 mg contains 180 mg of eicosapentaenoic acid (EPA) and 120 mg of docosahexaenoic acid (DHA). It provided about 4930 Kcal/kg diet [6].

2.3. Food intake measurement

The food was placed daily for each group *ad libitum* and the residual food was weighed. Food intake for each group equals the amount of food placed minus the residual food [7].

2.4. Body weight and body mass index (BMI) measurement

The body weight and length were measured at the start and the end of experiment. For detection of the initial and final body mass index (BMI), the following formula was used [8]:

$$BMI = \text{Body weight (gm)} / \text{Length}^{2} \ (cm^2)$$

End of the experiment and blood sampling for assay of:

2.5. Chemical measurements

- Serum glucose level by using direct colorimetric method (Bio-diagnostic Company, Egypt, CAT. NO. GL 13 20).
- Serum insulin by enzyme-linked immunosorbent assay (ELISA) (Thermo Fisher Scientific Company, United States, CAT. NO. ERINS).
- Serum leptin by ELISA (Abcam Company, Cambridge, United Kingdom, CAS. NO. ab100773).

2.6. Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) calculation *[9]*

HOMA-IR = {Fasting serum glucose (mmol/L) x Fasting serum insulin (μU/ml)}/22.5

3. Results

These previous results reveal that HFD group showed a significantly elevated food intake, body weight, serum glucose, insulin, leptin and HOMA-IR compared to other groups. PUFAs group showed a significant improvement regarding all parameters.

4. Discussion

The current study aimed to explore the satiating effect of the consumption of polyunsaturated fatty acids and its impact on metabolic health including glucose homeostasis, insulin secretion, and the cellular insulin response. While it was documented that fats may contribute to the feeling of fullness in some previous studies, others reported that unbalanced high-fat diets might lead to a decrease in satiety [10]. In the current study, there was an increased daily food intake in the high- neutral fat diet (HFD) group. This result may be explained by its palatability and affection on the secretion of ghrelin from the stomach, leading to an increase in hunger signals and a decrease in feelings of fullness [11]. Leptin in this study was significantly increased in the HFD group. Leptin is released from adipocytes and has a central satiating effect. This effect did not occur in the present study probably due to the development of leptin resistance. The accumulation of excess fat, due to consumption of HFD, is associated with increased production of inflammatory molecules which may interfere with leptin signaling, contributing to resistance [12]. This was not the case in the polyunsaturated fatty acids (PUFAs) group which showed a significantly lower food intake compared to other groups. This may be interpreted by enhancing the pathways involved in appetite regulation, promoting the gut microbiota composition that plays a role in regulating metabolism and signals between the gut and the brain [13]. PUFAs, particularly omega-3 fatty acids, may enhance the sensitivity of cells to leptin. Thus, the brain receives signals indicating satiety more effectively, leading to a reduction in food intake [14]. This was indicated by the lower serum level of leptin in the group that received a diet rich in PUFAs as compared to the HFD group which showed a significantly increased serum leptin. The unbalanced food intake with inadequate physical activity may contribute to the accumulation of fats in the body [15]. This was indicated by an increased body weight and body mass index (BMI) in the HFD group compared to the PUFAs group which showed a noticeable lower body weight and BMI. Diets rich in saturated fats are crucial contributors to the development of insulin resistance. This was indicated by the increased fasting glucose, insulin, and HOMA-IR levels in the HFD group. This result was previously documented by Kojta et al., [16] who reported that the accumulation of intracellular lipids can trigger an inflammatory response that may interfere with the normal insulin signaling pathways. It may also induce cellular stress, including endoplasmic reticulum (ER) stress which is responsible for protein synthesis and folding, and when overwhelmed with lipids, it triggers the unfolded protein response leading to the activation of inflammatory pathways. While the group that received a diet rich in PUFAs showed an improvement regarding HOMA-IR. This result may be demonstrated by enhancing glucose uptake by cells. PUFAs may also modulate the activity of protein kinases, such as protein kinase C (PKC) and c-Jun N-terminal kinase (JNK), which can negatively impact insulin signaling and thus, this may protect insulin receptor substrate (IRS) proteins from inhibitory phosphorylation, which are crucial for signals involved in glucose uptake and metabolism [17].

Table 1: Differences of food intake and body weight in different groups

	Control	HFD group	PUFAs group
Average Food intake/group (gm/day)	161.12 ± 0.72	186.83^{a} ± 0.6	145.5^{ab} ± 0.75
Final body weight/rat (gm)	230.5 ± 5.5	270.75^{a} ± 7.32	232^{b} ± 6.54
Final BMI (gm/cm^2)	0.6 ± 0.0	0.75^{a} ± 0.02	0.62^{b} ± 0.01

Data represent mean ± S.E of observations. a: significant difference from the control group, b: significant difference from the HFD group. Significance: $p \leq 0.05$. BMI: body mass index.

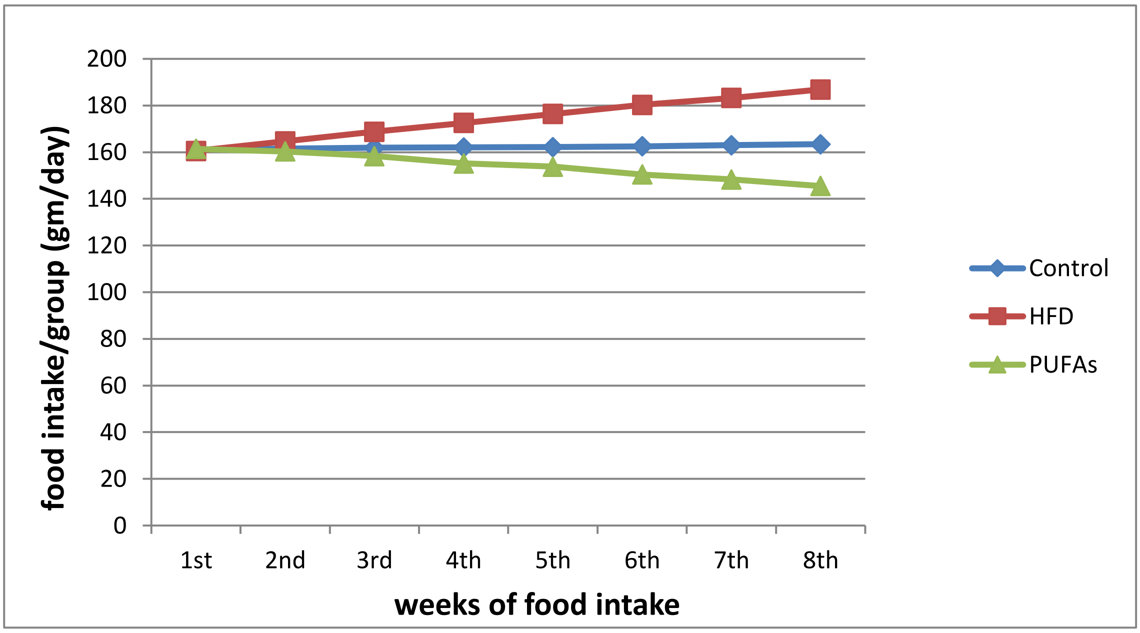

Figure 1: Food intake throughout the experiment

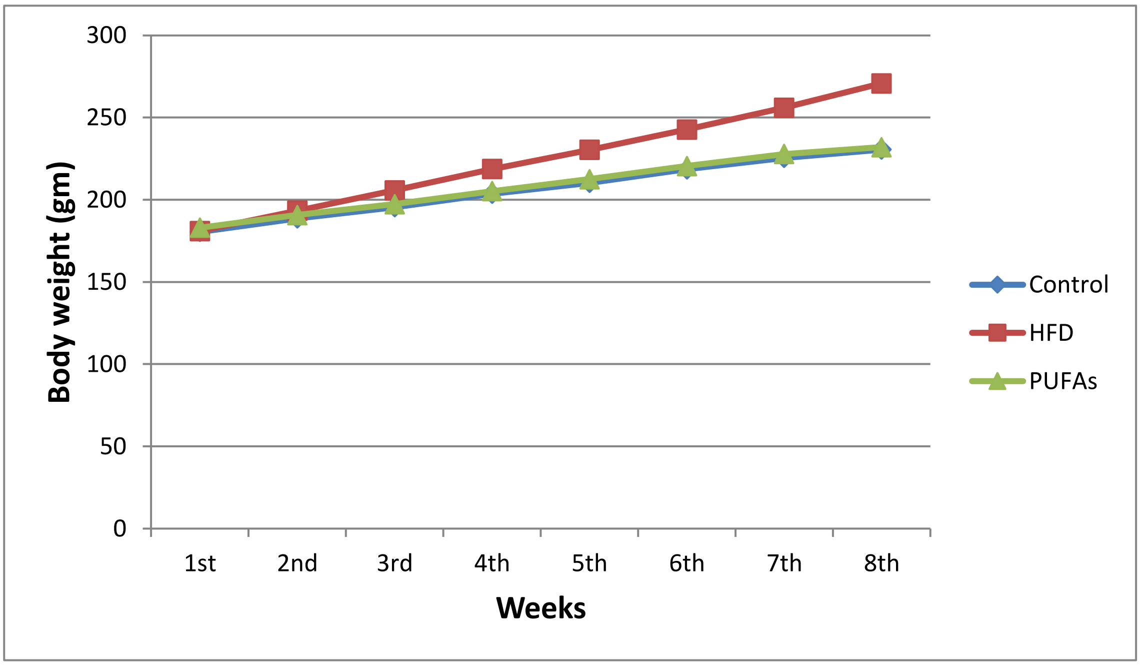

Figure 2: Changes of body weight throughout the experiment

Table 2: Differences in fasting glucose, insulin, and HOMA-IR in different groups

	Control	HFD group	PUFAs group
Fasting insulin (µU/ml)	8.78 ± 0.22	20.71^a ± 2	9^b ± 0.22
Fasting glucose (mmol/L)	5 ± 0.01	7.9^a ± 0.1	5.6^b ± 0.03
HOMA-IR	1.95 ± 0.07	7.27^a ± 1.5	2.24^b ± 0.09
Leptin (ng/ml)	0.24 ± 0.001	0.38^a ± 0.003	0.26^b ± 0.003

Data represent mean ± S.E of observations. a: significant difference from the control group, b: significant difference from the HFD group. Significance: $p \leq 0.05$. HOMA-IR: Homeostasis Model Assessment of Insulin Resistance.

5. Conclusion

According to our data in the current study, we concluded that incorporating PUFAs into a well-balanced diet can support overall health, including appetite regulation and satiety. The potential satiating effect of PUFAs may contribute to the improvement of insulin sensitivity and have a positive impact on the overall metabolic functions of the body including glucose metabolism, leptin sensitivity, and adipose tissue function.

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