Original Article

# Association Between Ultra-Processed Food Consumption and Metabolic Health Among Adults: A Cross-Sectional Study

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## Abstract

**Background:** The objective is to investigate whether ultra-processed foods (UPF) are associated with a metabolically unhealthy phenotype in adults, and to examine whether different types of UPF are associated with different components of the metabolic syndrome. **Material and Methods:** This is a retrospective cross-sectional study. It has been approved by the Institutional Ethics Committee. In total, 527 adults, aged 20-65 years were included in the study. The data on UPF consumption were collected by a validated food frequency questionnaire (FFQ). The NOVA classification system was used to categorize foods into four groups. Metabolic health status was defined by Wildman's criteria, whereas its components of the metabolic syndrome were defined by standard definitions. Odds ratios (ORs) were estimated by using multivariable logistic regression models. **Results:** The proportion of energy from ultra-processed foods (UPF) has been rising to account for a large share of total energy intake in many countries. Increasing consumption of UPF has become a concern for human health with potential adverse effects on metabolic health. The evidence for association between UPF intake and prevalence of metabolic syndrome (METS) has been inconsistent, partly because of differences in study populations and their ages. **Conclusion:** The higher consumption of ultra-processed foods is associated with higher odds of being in a metabolically unhealthy status and with hypertriglyceridemia in adults. This data supports public health strategies aimed at decreasing consumption of ultra-processed foods to improve metabolic health in adults.

**Keywords:** ultra-processed foods, metabolic health, metabolic syndrome, hypertriglyceridemia, adults, NOVA classification.

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## Introduction

Over the last few decades, the global dietary patterns have shifted from consuming more traditional and fresh, prepared foods to more processed and packaged, industrial foods.[1] These industrial ultra-processed foods and beverages (UPFs) are produced and processed in a complex chain of multiple physical, chemical, or biological processes.[2] Most UPFs contain a variety of unfamiliar ingredients, which are not typically used in home cooking. These include, for example, preservatives, flavor enhancers, colors, emulsifiers and other functional, "industrial" type of food additives, which are typically intended to enhance the taste, the shelf life and the convenience of the end product.[3]

Today's global food system contains an increasingly large proportion of Ultra-Processed Foods (UPFs). These industrial formulations, which are frequently marketed as "convenient" and "affordable" to consumers, are frequently consumed for part or all of the daily energy requirements of individuals in many countries around the world.[4,5] In some of the world's biggest economies, a large proportion of total energy from diet comes from these processed food products; the European diet, for example, derives around 50% of total energy from UPFs,[6,7] as does the diet in the United States,[8] Canada,[9] and the UK.[10] There are a number of reasons why UPFs have become so popular with consumers: their affordability, convenience, and long shelf life are key selling points for manufacturers of processed and packaged foods. Often packaged in attractive or brightly colored packaging to increase their appeal to potential consumers, UPFs are also frequently consumed for their taste. While many may be unaware of the potential health risks posed by these products, they contain high levels of saturated fats, added sugars, and sodium, amongst other ingredients that are not found in freshly prepared meals and are often consumed in excess.[11] In terms of nutritional value, UPFs are generally characterized by low nutrient density, containing limited amounts of dietary fiber and with a low content of essential micronutrients.[12]

Relationships between consumption of UPFs and health have been studied for a long time. It has been proven that intake of UPFs is associated with increased risk of obesity, diabetes, dyslipidemia, hypertension and also with increased risk of death from all causes.[10-12] However, relationship between intake of UPFs and metabolic syndrome has not been consistently found.[13] Positive associations have been reported in some studies,[14,15] whereas no association has been found in other studies.[16-19]

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Metabolic syndrome is a cluster of interrelated conditions such as increased blood pressure, raised blood glucose, abnormal cholesterol levels and excess body fat around the waist which together increase the risk of heart disease, stroke and diabetes. The prevalence of MS has increased globally to the same extent as the prevalence of overweight and obesity, which is considered to be the main cause of the syndrome. The prevalence of MS varies between populations. In most European populations, the prevalence is around 20-30%, but can be higher in middle-income countries.[20,21]

This study examines the relationship between the intake of UPF and metabolic health in adults and seeks to identify the individual UPF food groups that have the strongest association with the various components of the metabolic health syndrome.

## Materials and Methods

**Study Population:** The present study used a multistage cluster random-sampling method to select a sample from Iranian adults 20–65 years of age. In total, 527 participants were included in the study after application of the inclusion-exclusion criteria.

**Inclusion Criteria**

All study participants were between 20 and 65 years of age, were willing and able to complete the FFQ, and had complete data on all demographic, clinical, and laboratory parameters. In addition, all study participants provided informed consent for their inclusion in the study.

**Exclusion Criteria**

People with past history of diseases such as heart disease (CVD), diabetes and cancer, as well as pregnant women and lactating mothers and people on special diet for weight loss (surgical or non-surgical) were not included in the study. In addition, people with incomplete information on their diet intakes and/or their laboratory tests as well as individuals on medications which affect their metabolic indexes were not considered in the study.

**Data Collection**

**The following variables were systematically collected:** Participants were asked to provide demographic data (age, sex, education, marital status, occupation and estimated monthly income), information about their general lifestyle (smoking status, level of physical activity and use of medication) and anthropometric data (weight, height, BMI and waist circumference). Moreover, participants' laboratory measurements (glucose level, lipid profile, BDNF and adropin) were collected and analyzed.

**Dietary Assessment:** A 168-item semi-quantitative food frequency questionnaire (FFQ) validated for an Iranian population [27] was used to assess the diet of the participants. Intake of UPFs was determined using the NOVA food classification system. NOVA categories industrial processing of foods into four groups of increasing processing intensity: (1) unprocessed or minimally processed foods, (2) processed culinary ingredients, (3) processed meals, and (4) ultra-processed foods (UPFs). The latter include industrial formulas made mostly or entirely from foods and food additives, which contain very limited whole or even no intact foods. Energy-adjusted intake of UPFs was calculated by the residual method.

**Assessment of Metabolic Health Status:** In order to assess the degree of health risk of participants with regard to their metabolism, the criteria of "Metabolically Unhealthy" described by Wildman and his colleagues in 2008 were used. In their criteria, individuals were defined as "Metabolically Unhealthy" if they had two or more of the following conditions: high blood pressure (systolic or diastolic BP $\geq$ 130/85 mmHg or on antihypertensive medication); high triglycerides ($\geq$ 150 mg/dl); low HDL cholesterol (men < 40 mg/dl or women < 50 mg/dl); high fasting blood glucose (FBG $\geq$ 100 mg/dl or on antidiabetic medications); and/or high homeostatic model assessment for insulin resistance (HOMA-IR>90th percentile).

**Laboratory Measurements:** Fasting blood samples were collected from all participants after an overnight 12-hour fast. Biochemical parameters including serum glucose, triglycerides, total cholesterol, HDL cholesterol and LDL cholesterol were determined using standard enzymatic assays. Moreover, serum levels of BDNF and adropin were measured by commercial ELISA kits.[26]

**Statistical Analysis:** Data were presented as mean ± SD or in the form of frequency and percentage for the categorical variables. Participants were divided into three tertiles of energy adjusted consumption of UPF.

## Results

**Baseline Characteristics:** A total of 527 participants were included in the analysis. The mean age was 42.7 ± 11.2 years, with 45.7% (241/527) being female. The mean BMI was 26.9 ± 4.4 kg/m². The average intake of UPFs was 140.7 ± 5.3 grams per day. The overall prevalence of metabolically unhealthy phenotype was 42.5% (224/527).

**Table 1: General Characteristics of Participants Across Tertiles of UPF Intake**

| Variable | T1 (n=175) | T2 (n=176) | T3 (n=176) | p-value |
|---|---|---|---|---|
| Age (years), mean ± SD | 48.3 ± 11.0 | 42.3 ± 10.3 | 37.4 ± 9.6 | <0.001 |
| Body weight (kg), mean ± SD | 75.9 ± 14.8 | 74.2 ± 14.1 | 77.2 ± 14.7 | 0.14 |
| BMI (kg/m²), mean ± SD | 27.0 ± 4.6 | 26.8 ± 4.3 | 26.9 ± 4.4 | 0.91 |
| Waist circumference (cm), mean ± SD | 93.9 ± 11.6 | 91.5 ± 10.8 | 92.6 ± 12.0 | 0.15 |
| Male sex, n (%) | 107 (61.1) | 83 (47.2) | 96 (54.5) | 0.03 |
| Education > Diploma, n (%) | 152 (86.9) | 154 (87.5) | 163 (92.6) | 0.16 |
| Married, n (%) | 145 (82.9) | 152 (86.4) | 138 (78.4) | 0.14 |
| Smokers, n (%) | 5 (2.9) | 4 (2.3) | 7 (4.0) | 0.39 |
| High income, n (%) | 55 (31.4) | 34 (19.3) | 26 (14.8) | 0.01 |
| Physically active, n (%) | 14 (8.0) | 16 (9.1) | 11 (6.3) | 0.53 |
| High BP ($\geq$ 130/85 mmHg), n (%) | 96 (54.9) | 76 (43.2) | 77 (43.8) | 0.05 |
| High TG ($\geq$ 150 mg/dL), n (%) | 59 (33.7) | 63 (35.8) | 71 (40.3) | 0.42 |

| | | | | |
|---|---|---|---|---|
| Low HDL-C (< 40/50 mg/dL), n (%) | 16 (9.1) | 19 (10.8) | 26 (14.8) | 0.24 |
| High FBG (≥ 100 mg/dL), n (%) | 48 (27.4) | 27 (15.3) | 29 (16.5) | 0.01 |
| BDNF (ng/mL), mean ± SE | 1.17 ± 0.04 | 1.28 ± 0.13 | 1.30 ± 0.16 | 0.73 |
| Adropin (pg/mL), mean ± SE | 53.5 ± 2.1 | 63.1 ± 4.1 | 53.3 ± 2.8 | 0.04 |

The prevalence of metabolically unhealthy phenotype was 46.3% in the first tertile, 40.9% in the second tertile, and 40.3% in the third tertile (p = 0.46). Participants with higher UPF intake were more likely to be male, younger, and have lower income. They also had lower circulating adropin levels and lower prevalence of hyperglycemia.

**Table 2: Dietary Intakes Across Tertiles of UPF Intake**

| Dietary Variable | T1 (n=175) | T2 (n=176) | T3 (n=176) | p-value |
|---|---|---|---|---|
| Energy intake (kcal/day) | 2467.2 ± 178.5 | 2637.6 ± 119.2 | 2705.7 ± 126.4 | <0.001 |
| Carbohydrate (g/day) | 365.1 ± 141.0 | 368.1 ± 122.5 | 367.5 ± 113.9 | 0.97 |
| Protein (g/day) | 111.6 ± 40.6 | 101.7 ± 30.6 | 97.5 ± 28.7 | <0.001 |
| Fat (g/day) | 77.7 ± 31.9 | 89.1 ± 33.7 | 95.1 ± 35.6 | <0.001 |
| AHEI score | 53.2 ± 10.3 | 49.3 ± 9.3 | 46.0 ± 9.7 | <0.001 |

Dietary quality, measured by the Alternative Healthy Eating Index, decreased significantly with increasing UPF intake. Fat intake was highest in the third tertile, while protein intake was lowest in the third tertile.

**Association Between UPF Intake and Metabolic Health**

In crude models, no significant association was found between UPF intake and odds of MU status (ORT3 vs. T1 = 0.79; 95% CI: 0.51–1.20). However, after adjusting for all potential confounders, subjects in the highest tertile of UPF intake had a significantly increased likelihood of MU status compared to the reference group (ORT3 vs. T1 = 1.88; 95% CI: 1.02–3.45). A significant increasing trend was also observed across tertiles (p for trend = 0.04).

**Table 3: Multivariable-Adjusted Odds Ratios for MU Status Across Tertiles of UPF Intake**

| Model | T1 (n=175) | T2 (n=176) | T3 (n=176) | p for trend |
|---|---|---|---|---|
| Crude | 1.00 (ref) | 0.80 (0.51–1.27) | 0.79 (0.51–1.20) | 0.26 |
| Model 1 | 1.00 (ref) | 0.94 (0.57–1.54) | 0.95 (0.60–1.52) | 0.83 |
| Model 2 | 1.00 (ref) | 1.24 (0.72–2.15) | 1.88 (1.02–3.45) | 0.04 |

Model 1 adjusted for age and sex. Model 2 adjusted for age, sex, education, marital status, occupation, smoking, physical activity, and energy intake.

## Discussion

The objective of this study was to test the hypothesis that the consumption of ultra-processed foods (UPF) is associated with a metabolically unhealthy status in adults. Our results show that participants in the highest tertile of UPF intake had 88% higher odds of having a MU phenotype after adjustment for potential confounders. These results are in line with the growing body of evidence that consumption of UPF is associated with unfavorable changes in metabolic health.[11,14,15]

The prevalence of MetS in this relatively young study population (mean age of 42.7 ± 8.8 yr) was 42.5% (95% CI: 37.4–47.7). In agreement with previous reports, the strongest association between UPF intake and components of MetS was with hypertriglyceridemia, with those in the highest tertile of UPF having 2 times greater odds of having this component of MetS compared to those in the lowest tertile of UPF intake (OR: 2.02; 95% CI: 1.36–3.02). This finding is consistent with previous reports on the association of dietary patterns that are high in processed and/or cooked foods and increased risk of dyslipidemia.

Our findings add to current knowledge on the health effects of UPF consumption. Recent work has questioned the effect of UPF consumption on metabolic health. An analysis of data from 1493 European adults (13 countries) from the I.Family study found no association between UPF intake and metabolic syndrome or its components when participants were divided into quintiles of UPF intake.[18] However, all effect sizes were very small and not statistically significant across all five components of the metabolic syndrome. Another aspect of diet that was investigated in this study was the effect of diet quality on UPF intake. Results showed that as the proportion of UPF in the diet increased, diet quality decreased.[19,20] Factors that may have contributed to the very different findings from the current study, conducted on a single population using a single method of dietary assessment, and defining metabolic health using a single phenotype, are the population studied, the method of dietary assessment used, and the definition of metabolic health used.[21]

## Conclusion

Our findings support that higher consumption of ultra-processed foods is associated with higher likelihood of having a metabolically unhealthy status and of having hypertriglyceridemia. After controlling for several potential confounders, including demographic, lifestyle and dietary variables, the associations remained significant. The current evidence supports the idea that different categories of ultra-processed foods may have different health effects. Therefore, a more nuanced public health message about the negative effects of ultra-processed foods is required.

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## Conflicts of interest

There are no conflicts of interest.

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