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Ultra-Processed Food Consumption Patterns and Their Association with Lipid Profiles in Sedentary Adults

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ABSTRACT

Ultra-processed food (UPF) consumption and sedentary behavior are relevant to cardiometabolic health. This methodological demonstration illustrates a cross-sectional analytical framework for examining UPF-derived energy intake and fasting lipid profiles among sedentary adults. A synthetic dataset comprising 240 simulated observations was used; no participants were recruited and no laboratory tests were performed. UPF intake was classified using the NOVA system and analyzed in tertiles and as a continuous percentage of energy intake. Illustrative multivariable linear models adjusted for age, sex, body mass index, smoking, alcohol intake, energy intake, dietary fiber, and physical activity. The supplied synthetic estimates showed higher total cholesterol (β=5.11 mg/dL), LDL-C (β=4.33 mg/dL), and triglycerides (β=14.71 mg/dL), and lower HDL-C (β=−2.05 mg/dL), per 10-percentage-point increase in UPF-derived energy. These numerical associations reflect a simulated scenario, not observed biological relationships. The data-generation algorithm, random seed, and regression diagnostics were not available for independent verification. Accordingly, these estimates must not be interpreted as empirical evidence or used to inform clinical decisions. Actual participant data and reproducible analyses are necessary to test the proposed hypothesis.

INTRODUCTION

Cardiovascular disease remains a major public-health concern, with dyslipidemia representing an important modifiable component of cardiovascular risk. Abnormal concentrations of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and triglycerides (TG) are influenced by multiple behavioral and metabolic factors, including dietary patterns, adiposity, smoking, physical activity, and sedentary behavior. Contemporary lifestyles increasingly combine prolonged sitting with easy access to highly processed, ready-to-consume foods, creating a behavioral pattern that may adversely affect cardiometabolic health.

Ultra-processed foods (UPFs) are commonly identified using the NOVA food-classification system, which categorizes foods according to the nature, extent, and purpose of industrial processing. UPFs are industrial formulations typically containing food-derived substances and additives such as flavors, colors, emulsifiers, sweeteners,

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modified starches, and other ingredients that are uncommon in domestic culinary preparation (Monteiro et al., 2019). This category includes many packaged snacks, sugar-sweetened beverages, processed meat products, instant foods, confectionery products, and ready-to-eat meals.

The nutritional characteristics of UPF-rich dietary patterns provide several plausible pathways for adverse metabolic effects. UPFs may contribute disproportionately to added-sugar intake and can be characterized by high energy density, refined carbohydrates, sodium, and selected fats while displacing minimally processed foods rich in dietary fiber and intact food structures (Martínez Steele et al., 2016; Monteiro et al., 2019). Experimental evidence also suggests that processing-related characteristics may influence food intake independently of conventional nutrient composition. In a controlled inpatient randomized trial, Hall et al. (2019) demonstrated that participants consuming an ultra-processed diet had substantially greater ad libitum energy intake and gained weight compared with those consuming an unprocessed diet.

Evidence linking UPF consumption with adverse health outcomes has expanded considerably. A systematic review and meta-analysis of prospective cohort studies reported associations between greater UPF consumption and increased risks of diabetes, hypertension, hypertriglyceridemia, low HDL-C, and obesity (Vitale et al., 2024). Similarly, an umbrella review of epidemiological meta-analyses found that greater UPF exposure was associated with multiple adverse outcomes, with particularly important signals for cardiometabolic disease and mortality, although the certainty of evidence varied across outcomes (Lane et al., 2024). An additional umbrella review and updated meta-analysis also supported broad associations between UPF exposure and adverse health outcomes (Dai et al., 2024).

Prospective cardiovascular studies provide further evidence. In the NutriNet-Santé cohort, greater UPF consumption was associated with increased risks of cardiovascular, coronary, and cerebrovascular disease (Srour et al., 2019). The Framingham Offspring Study subsequently demonstrated that greater UPF consumption was associated with incident cardiovascular disease and cardiovascular mortality (Juul et al., 2021). More recently, a systematic review and dose-response meta-analysis identified a positive relationship between UPF intake and cardiovascular events (Qu et al., 2024), while an analysis of three large US cohorts similarly supported an association between total UPF intake and cardiovascular disease but highlighted important differences among individual UPF subgroups (Mendoza et al., 2024).

UPF consumption has also been linked to several metabolic conditions that commonly coexist with dyslipidemia. Higher consumption has been associated with type 2 diabetes in large prospective US cohorts (Chen et al., 2023), obesity (Dicken & Batterham, 2024), and incident hypertension (Oladele et al., 2024). Long-term prospective evidence has additionally examined UPF consumption in relation to all-cause and cause-specific mortality (Fang et al., 2024). Together, these findings suggest that UPF consumption may contribute to a broader cardiometabolic risk profile rather than affecting a single metabolic endpoint.

Blood lipid abnormalities represent a plausible intermediate pathway connecting UPF-rich diets with cardiovascular outcomes. Recent evidence is beginning to clarify this relationship. Millar et al. (2024), for example, found that greater ultra-processed food and drink consumption was associated with lower HDL-C, alterations in LDL and HDL particle size, greater concentrations of selected atherogenic lipoprotein subclasses, and higher lipoprotein insulin-resistance scores. Meta-analytic evidence has likewise

identified increased risks of hypertriglyceridemia and low HDL-C among individuals with greater UPF exposure (Vitale et al., 2024).

Sedentary behavior may provide an additional metabolic context in which these dietary associations are relevant. The World Health Organization (2020) recommends limiting sedentary time and replacing sedentary behavior with physical activity whenever possible because prolonged sedentary exposure is associated with adverse health outcomes. Prolonged sitting reduces skeletal-muscle contractile activity and daily energy expenditure and may adversely influence glucose disposal and lipid metabolism. Importantly, sedentary behavior and insufficient moderate-to-vigorous physical activity are related but distinct exposures.

Despite the rapidly expanding UPF literature, fewer studies have specifically examined lipid profiles among adults characterized by high sedentary exposure. Existing research has typically evaluated UPF consumption in broader populations or focused on cardiovascular disease, obesity, diabetes, or mortality. Consequently, evidence remains comparatively limited regarding whether increasing UPF exposure is associated with a progressively unfavorable lipid profile within a predominantly sedentary adult population.

Therefore, the present analytical study was designed to examine the association between the proportion of dietary energy derived from UPFs and fasting lipid profiles among sedentary adults. The primary hypothesis was that greater UPF intake would be associated with higher TC, LDL-C, and TG and lower HDL-C after adjustment for demographic, anthropometric, dietary, and behavioral covariates.

METHODOLOGY

Study Design

The analytical framework used a cross-sectional design involving adults aged 18–59 years with predominantly sedentary daily routines. For the purposes of the present manuscript demonstration, the statistical analyses were performed using a synthetic dataset of 240 participants generated to reproduce the prespecified study design and hypothesized relationships. The synthetic observations do not represent recruited human participants, clinical records, or actual laboratory measurements and should not be interpreted as empirical field data.

Accordingly, the methodology described below represents the intended protocol for an empirical implementation of the study, whereas the numerical results reported in the Results section are explicitly illustrative analyses derived from synthetic data.

Scope of this demonstration: The synthetic numbers were supplied as an illustrative analytical example. The underlying observation-level dataset, generation script, distributional assumptions, and random seed were not provided with the manuscript. Consequently, the data-generation procedure cannot be independently reconstructed or validated from the information currently available. Any empirical implementation must document recruitment, measurements, data cleaning, and the complete reproducible analytical workflow.

Participants and Eligibility Criteria

The target population consisted of adults aged 18–59 years whose daily routines involved substantial sedentary exposure. Sedentary status was operationalized as approximately ≥8 hours/day of sitting or other low-energy waking behavior. For an empirical implementation, eligible participants would be adults capable of completing dietary and physical-activity assessments and undergoing fasting blood collection. Exclusion criteria

would include pregnancy or breastfeeding, acute illness, medically prescribed diets substantially affecting habitual food intake, lipid-lowering medication unless explicitly modeled, and incomplete dietary or biochemical information.

Analytical Sample

The synthetic analytical dataset contained 240 observations. Participants were categorized into tertiles according to the percentage of total dietary energy derived from UPFs, resulting in 80 observations each in the low (T1), moderate (T2), and high (T3) UPF groups. The sample size was selected to permit comparison across UPF-intake tertiles and estimation of multivariable associations involving major demographic, anthropometric, dietary, and behavioral covariates. Because the dataset is synthetic, this sample size should not be interpreted as an empirical recruitment count or as a substitute for an a priori sample-size calculation in a real study.

Dietary Assessment and NOVA Classification

Procedure distinction: The dietary-recall instruments and NOVA coding procedures above describe a proposed future field protocol only. No questionnaires, food records, or dietary interviews were administered for the numerical results in this manuscript. The UPF percentages used in the tables represent simulated values rather than assessed dietary intake.

In the intended empirical protocol, habitual dietary intake should be assessed using a validated semi-quantitative food-frequency questionnaire, repeated 24-hour dietary recalls, or multi-day food records. Foods and beverages should subsequently be classified according to the NOVA system into: (1) unprocessed or minimally processed foods; (2) processed culinary ingredients; (3) processed foods; and (4) ultra-processed foods (Monteiro et al., 2019). The principal exposure variable was defined as the percentage of total daily energy derived from UPFs:

UPF energy (%) = (daily energy from UPFs / total daily energy intake) × 100

UPF intake was evaluated both categorically according to tertiles and continuously per 10-percentage-point increase in total energy derived from UPFs.

Sedentary Behavior and Physical Activity

Sedentary exposure was represented as hours of sedentary time per day. Moderate-to-vigorous physical activity (MVPA) was represented as minutes per week and included as a covariate because sedentary behavior and physical activity represent distinct behavioral constructs. In an empirical study, sedentary behavior should preferably be measured using an accelerometer worn for at least seven consecutive days. When device-based measurement is not feasible, a validated questionnaire may be used to quantify occupational sitting, transportation, television viewing, computer use, and other seated activities. Measurement and interpretation should follow established recommendations concerning physical activity and sedentary behavior (World Health Organization, 2020).

Anthropometric Measurements

Body mass index (BMI) was expressed as weight in kilograms divided by height in meters squared (kg/m²). For empirical data collection, weight should be measured using a calibrated digital scale while participants wear light clothing and no shoes, and height should be measured using a standardized stadiometer.

Lipid Profile Assessment

The primary outcomes were fasting TC, LDL-C, HDL-C, and TG concentrations expressed in mg/dL. In an empirical study, venous blood should be collected after approximately 8–12 hours of overnight fasting. TC, HDL-C, and TG should be determined using standardized enzymatic methods, whereas LDL-C may be measured

directly or estimated using an accepted equation when TG concentrations are within the applicable analytical range. Because the present dataset is synthetic, the lipid values reported below were computationally generated rather than laboratory measured.

Covariates

Potential confounders included age, sex, BMI, smoking status, alcohol intake, total daily energy intake, dietary fiber intake, and MVPA. These variables were selected because they may be associated with dietary behavior and/or lipid metabolism.

Statistical Analysis

Model verification and reproducibility: Table 3 reproduces the regression estimates reported for the synthetic scenario. Because the observation-level dataset and model-fitting output are not available, residual normality, homoscedasticity, influential observations, multicollinearity, functional form, and model fit (including R^2) cannot be assessed or reported reliably. The displayed confidence intervals and p-values are illustrative and are not independently verified. A reproducible version should provide the generation algorithm and seed, analysis code, complete variable definitions, and standard regression diagnostics before the figures are used to make methodological performance claims.

Continuous variables were summarized using means and standard deviations, whereas categorical variables were represented using frequencies and percentages where appropriate. Participants were divided into tertiles according to the percentage of total energy derived from UPFs. Multivariable linear regression was used to estimate associations between UPF intake and continuous lipid outcomes. UPF intake was modeled continuously per 10-percentage-point increase in total energy derived from UPFs. Adjusted models included age, sex, BMI, smoking status, alcohol intake, total energy intake, dietary fiber intake, and MVPA.

Regression coefficients (β), 95% confidence intervals (95% CI), and two-sided p-values were reported. Statistical significance was defined as $p<0.05$.

Ethical Considerations

Because the numerical analysis presented in this manuscript uses a synthetic dataset and does not involve actual human participants or identifiable human data, the synthetic analysis itself did not require participant recruitment, informed consent, blood collection, or institutional ethics approval. If the study is subsequently conducted using actual human participants, ethical approval must be obtained from an appropriate institutional ethics committee before recruitment, and all participants must provide informed consent. The actual committe name, approval number, and approval date must then replace this statement. No ethics approval number should be fabricated or retrospectively assigned.

RESULTS AND DISCUSSION

Results

Participant Characteristics

The synthetic analytical sample consisted of 240 observations divided equally across three UPF-intake tertiles (n=80 per tertile). As shown in Table 1, age and daily sedentary exposure were relatively similar across groups. In contrast, increasing UPF consumption was accompanied by a modest increase in BMI and total energy intake and a decline in dietary fiber intake.

Table 1. Characteristics of the Synthetic Sample According to UPF-Intake Tertiles

Characteristic	T1: Low UPF	T2: Moderate UPF	T3: High UPF
Observations, n	80	80	80

Age, years	37.8 ± 9.8	38.3 ± 10.1	38.5 ± 9.9
BMI, kg/m²	24.1 ± 2.5	24.7 ± 2.6	25.2 ± 2.5
Sedentary time, hours/day	9.4 ± 0.9	9.4 ± 1.0	9.5 ± 1.0
MVPA, min/week	107.0 ± 54.0	105.0 ± 56.0	103.0 ± 55.0
Total energy, kcal/day	1,680 ± 260	1,760 ± 270	1,850 ± 280
Dietary fiber, g/day	22.0 ± 3.1	20.8 ± 3.0	19.4 ± 3.0
UPF intake, % energy	24.0 ± 7.0	39.0 ± 4.5	55.0 ± 8.0

Note: Synthetic data; values are mean ± standard deviation unless otherwise stated. UPF = ultra-processed food; BMI = body mass index; MVPA = moderate-to-vigorous physical activity.

Lipid Profiles According to UPF Intake

The synthetic data were generated to reflect the hypothesized relationship between UPF exposure and lipid metabolism. Consequently, a progressive gradient was observed across UPF-intake tertiles (Table 2). Mean TC increased from 181.0 ± 21.9 mg/dL in T1 to 199.9 ± 19.0 mg/dL in T3. LDL-C increased from 100.7 ± 18.2 to 117.0 ± 16.4 mg/dL. The largest absolute difference was observed for TG, which increased from 99.5 ± 24.4 mg/dL in T1 to 138.6 ± 25.8 mg/dL in T3. Conversely, HDL-C decreased from 61.0 ± 6.7 to 55.0 ± 7.3 mg/dL.

Table 2. Fasting Lipid Profiles Across UPF-Intake Tertiles in the Synthetic Dataset

Lipid parameter	T1: Low UPF	T2: Moderate UPF	T3: High UPF
Total cholesterol, mg/dL	181.0 ± 21.9	190.0 ± 20.5	199.9 ± 19.0
LDL-C, mg/dL	100.7 ± 18.2	108.2 ± 17.4	117.0 ± 16.4
HDL-C, mg/dL	61.0 ± 6.7	57.8 ± 7.0	55.0 ± 7.3
Triglycerides, mg/dL	99.5 ± 24.4	120.6 ± 28.0	138.6 ± 25.8

Note: Synthetic data; values are mean ± standard deviation.

Multivariable Associations

In the synthetic multivariable analysis, greater UPF exposure remained associated with the four lipid outcomes after adjustment for age, sex, BMI, smoking, alcohol intake, total energy intake, dietary fiber, and MVPA (Table 3).

Table 3. Multivariable Associations Between UPF Intake and Lipid Profiles in the Synthetic Dataset

Outcome	Adjusted β per 10% increase in UPF	95% CI	*p*-value
Total cholesterol	5.11	2.34 to 7.88	<0.001
LDL-C	4.33	2.02 to 6.64	<0.001
HDL-C	−2.05	−3.00 to −1.10	<0.001
Triglycerides	14.71	11.17 to 18.26	<0.001

***Note: Synthetic data. Models adjusted for age, sex, BMI, smoking status, alcohol** intake, total energy intake, dietary fiber intake, and MVPA. β represents the modeled difference in lipid concentration (mg/dL) for each 10-percentage-point increase in UPF-derived*

energy. Within this synthetic model, each 10-percentage-point increase in UPF-derived energy corresponded to a 5.11 mg/dL higher TC (95% CI 2.34–7.88), 4.33 mg/dL higher LDL-C (95% CI 2.02–6.64), and 14.71 mg/dL higher TG (95% CI 11.17–18.26). HDL-C was 2.05 mg/dL lower (95% CI −3.00 to −1.10). All modeled associations had $p<0.001$.

Discussion

Because these numerical findings were generated from synthetic data, they should be interpreted as a demonstration of the **pattern that the proposed empirical study is designed to test**, rather than evidence that such effects were observed in recruited participants. Nevertheless, the modeled direction of association can be compared with existing empirical literature to assess whether the analytical scenario is biologically and epidemiologically plausible.

The synthetic analysis produced a progressively less favorable lipid profile with increasing UPF exposure. TC, LDL-C, and TG increased across UPF tertiles, whereas HDL-C decreased. This modeled pattern is broadly consistent with prospective meta-analytic evidence. Vitale et al. (2024) reported that greater UPF consumption was associated with increased risks of hypertriglyceridemia and low HDL-C, although the authors also emphasized that effect estimates differed according to methods used to assess UPF consumption.

The strongest modeled relationship was observed for TG. Each 10-percentage-point increase in UPF-derived energy corresponded to a 14.71 mg/dL increase in TG in the synthetic regression. This direction is biologically plausible because diets rich in UPFs may contain substantial quantities of rapidly digestible carbohydrates and added sugars while providing comparatively less fiber and intact food structure (Martínez Steele et al., 2016; Monteiro et al., 2019). Greater intake of refined carbohydrates and sugars may promote hepatic lipogenesis and contribute to elevated circulating TG.

Experimental evidence provides an additional mechanism. Hall et al. (2019) demonstrated in a randomized inpatient study that an ultra-processed diet resulted in greater ad libitum energy intake and weight gain compared with an unprocessed diet. This finding suggests that texture, energy density, eating rate, palatability, and other characteristics of UPFs may influence energy balance beyond conventional nutrient composition. Excess energy intake and subsequent adiposity could consequently contribute to lipid abnormalities.

The synthetic analysis also modeled a positive relationship between UPF exposure and LDL-C. This direction is compatible with emerging empirical evidence concerning intermediate lipid biomarkers. Millar et al. (2024), in a cross-sectional study of 1,986 middle- to older-aged adults, found that greater ultra-processed food and drink consumption was associated with lower HDL-C and several alterations in lipoprotein subclasses, including changes consistent with a more pro-atherogenic and insulin-resistant metabolic profile.

The inverse relationship with HDL-C modeled in the present dataset is particularly consistent with that study and with the prospective meta-analysis of Vitale et al. (2024). The combination of elevated TG and reduced HDL-C is potentially relevant because these abnormalities frequently occur within broader insulin-resistant and cardiometabolic phenotypes.

The cardiovascular literature provides additional context. Srour et al. (2019), using data from 105,159 participants in the NutriNet-Santé cohort, found that greater UPF intake was prospectively associated with cardiovascular, coronary, and cerebrovascular

disease. Juul et al. (2021) subsequently reported that each additional daily serving of UPFs was associated with increased cardiovascular outcomes in the Framingham Offspring Study.

More recent evidence has reinforced these observations. Qu et al. (2024), in a systematic review and dose-response meta-analysis involving more than one million participants, reported a positive relationship between UPF consumption and cardiovascular events. Mendoza et al. (2024), using three large US prospective cohorts combined with systematic-review evidence, likewise found an association between total UPF consumption and cardiovascular disease.

However, Mendoza et al. (2024) also highlighted an important qualification: individual UPF categories do not necessarily show identical relationships with cardiovascular outcomes. Their findings support a more nuanced interpretation in which products such as processed meats and sweetened beverages may differ from other foods classified as ultra-processed. Therefore, an association with total UPF exposure should not be interpreted as evidence that every food classified as UPF has an equivalent metabolic effect.

This issue is important because NOVA classifies foods according to the nature, extent, and purpose of processing rather than exclusively according to nutrient composition (Monteiro et al., 2019). UPFs consequently constitute a heterogeneous group. Future empirical implementation of the present study should therefore evaluate both overall UPF exposure and major subgroups such as sugar-sweetened beverages, processed meats, packaged snacks, instant foods, sweetened dairy products, and ready-to-eat meals.

The sedentary nature of the target population also deserves attention. WHO guidance recommends limiting sedentary time and replacing it with physical activity because sedentary behavior is associated with adverse health outcomes (World Health Organization, 2020). Prolonged sitting reduces skeletal-muscle contractile activity and total energy expenditure and may create a metabolic context in which unfavorable dietary patterns become particularly relevant.

Nevertheless, the present synthetic analysis does not demonstrate an interaction between sedentary behavior and UPF consumption. Such an interaction would require empirical observations and a prespecified interaction analysis. The appropriate interpretation is therefore that sedentary adults represent a clinically relevant population in which the diet–lipid relationship warrants investigation, rather than that sedentary behavior has been shown here to amplify the effect of UPFs.

The broader cardiometabolic literature supports investigating this relationship. Chen et al. (2023) found greater UPF consumption to be associated with increased type 2 diabetes risk across three large prospective US cohorts. Oladele et al. (2024) reported a positive association between UPF consumption and incident hypertension in the REGARDS cohort. Reviews have also examined the relationship between UPFs and obesity, with plausible pathways involving energy intake, dietary composition, food structure, and eating behavior (Dicken & Batterham, 2024).

At a broader level, Lane et al. (2024) synthesized meta-analytic evidence across numerous health outcomes and found that greater UPF exposure was associated with higher risks across several domains, particularly cardiometabolic outcomes and mortality. Importantly, however, the certainty of evidence varied considerably, and much of the evidence remains observational. Similar caution is necessary when interpreting associations with dyslipidemia.

Mortality research provides further context but should not be interpreted as proof of a direct causal pathway. Fang et al. (2024) reported associations between long-term UPF consumption and mortality outcomes in large US cohorts. Such findings reinforce the importance of investigating intermediate risk factors including lipid abnormalities but cannot by themselves determine whether processing, nutrient composition, dietary displacement, or correlated lifestyle characteristics are responsible for the associations.
Adiposity may also play multiple roles in the relationship between UPF intake and lipid metabolism. In the synthetic dataset, BMI increased modestly across UPF tertiles, while the modeled UPF–lipid associations remained after adjustment for BMI. In an empirical analysis, however, BMI should be interpreted carefully because it may function as both a confounder and an intermediate variable. If UPF intake increases energy intake and weight gain, as demonstrated experimentally by Hall et al. (2019), adjustment for BMI could remove part of the pathway through which UPFs influence metabolic outcomes.

Several limitations would need to be addressed when implementing the study empirically. A cross-sectional design cannot establish temporal sequence or causality. Dietary assessment may be affected by recall error, under-reporting, and misclassification of composite foods within NOVA categories. Residual confounding may persist even after adjustment for age, sex, BMI, smoking, alcohol, energy intake, dietary fiber, and MVPA. Socioeconomic status, sleep, occupational stress, medication use, genetic susceptibility, and detailed nutrient composition may also influence lipid concentrations. Most importantly, **the present numerical results cannot be interpreted as study findings because they originate from a deliberately generated synthetic dataset**. Their role is to demonstrate the planned analysis, expected table structure, and an epidemiologically plausible pattern against which future empirical results can be compared. Actual field data may produce smaller, larger, null, or directionally different associations.
This manuscript demonstrates a proposed analytical workflow using synthetic observations rather than reporting empirical research findings. The supplied illustrative estimates describe a modeled pattern of higher total cholesterol, LDL-C, and triglycerides and lower HDL-C with increasing UPF-derived energy. They do not show that these associations occur in human participants, and their uncertainty estimates have not been independently verified. No clinical, population-level, or causal conclusions can be drawn. A future study using real participant data, ethics approval, standardized measurement procedures, transparent data processing, and reproducible regression diagnostics is necessary to evaluate the hypothesis.

CONCLUSION

In this synthetic analytical demonstration, greater UPF intake was modeled as being associated with higher TC, LDL-C, and TG and lower HDL-C among sedentary adults after multivariable adjustment. The direction of these synthetic associations is broadly consistent with existing epidemiological and experimental literature. However, the numerical findings are not empirical participant results and cannot support clinical or causal conclusions. Future studies using actual participant data, standardized dietary assessment, objective sedentary-behavior measurement, fasting lipid testing, and prospective designs are required to determine whether these relationships occur in real sedentary adult populations

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