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**ORIGINAL ARTICLE**

# Ready-To-Eat Foods and Chronic Diseases Risk: A Mendelian Randomization Study

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**Abstract:**

**Background:** The rising prevalence of ready-to-eat foods in diets has raised health concerns due to their association with increased risks of chronic diseases. However, the specific biochemical impacts and potential causal relationships are not well understood, emphasizing a crucial area for public health research.

**Objective:** To explore the correlation between the frequency of ready-to-eat food consumption, chronic diseases, and blood biochemical indicators to identify potential biomarkers and assess their causal relationships with chronic diseases.

**Methods:** The study utilizes data from the National Health and Nutrition Examination Survey (NHANES), covering adults aged 18 to 80. The 24-hour dietary recall questionnaire determined the frequency of ready-to-eat food consumption. Employing Mendelian randomization (MR), the study used genetic variations linked to the most strongly correlated biochemical indicators as instrumental variables to assess their causal relationships with chronic diseases.

**Results:** Correlation analysis revealed significant associations between the consumption frequency of ready-to-eat foods and eight chronic diseases—diabetes, coronary heart disease, hypertension, asthma, angina, renal failure, apoplexy, and thyroid disease ($P<0.05$). Heatmap analysis underscored a significant correlation between hemoglobin (Hb) levels and the consumption frequency of ready-to-eat foods.

**Conclusion:** The study establishes strong links between the frequent consumption of ready-to-eat foods and increased risks of chronic diseases, accompanied by notable changes in blood biochemical markers such as hemoglobin. These findings underscore the potential public health impacts of such dietary habits and support the need for tailored nutritional interventions and health policy development.

**Keywords:** Ready-to-eat foods, Chronic diseases, Blood biochemical indicators, NHANES, Mendelian randomization.

## Introduction

Over the past few decades, global dietary patterns have shifted significantly, notably with a rapid increase in the consumption of ready-to-eat foods[1, 2]. Typically pre-processed and packaged for immediate consumption or minimal heating, these foods are popular in today's fast-paced lifestyle due to their convenience, taste, and variety. However, this convenience can obscure significant health risks. An increasing number of epidemiological studies[3, 4] are now examining the potential relationship between the consumption of ready-to-eat foods and various diseases.

Dietary habits, particularly those involving high caloric, high fat, high salt, and low fiber intake, are closely linked to the development of chronic diseases, including cardiovascular diseases and type 2 diabetes[5]. Long-term unhealthy dietary patterns, as shown in studies[6-8] can lead to weight gain, metabolic disorders, and

inflammatory responses, which are key risk factors for various chronic diseases. Particularly concerning is the excessive intake of trans fats, added sugars, and sodium, commonly found in ready-to-eat foods, which is closely linked to an increased risk of chronic diseases[9]. Trans fats, a type of unsaturated fat prevalent in food processing, are proven to increase the risk of heart disease and overall mortality. Excessive consumption of added sugars, particularly in soft drinks and desserts, is clearly associated with the onset of type 2 diabetes[10, 11]. Additionally, high-salt foods, often found in ready-to-eat items due to flavoring and preservation needs, are considered a major risk factor for hypertension and cardiovascular diseases[12].

Despite extensive epidemiological data linking ready-to-eat food consumption with increased chronic disease risk, research into the direct connections between consumption frequency, specific diseases, and their impacts via biological markers is still incomplete. Although it is known that high processed food intake is linked to obesity, cardiovascular diseases, and diabetes, studies often focus more on overall food intake and disease rates than on decoding the dynamic relationships between consumption frequency, disease progression, and biological mechanisms. Furthermore, few studies explore how the frequency of ready-to-eat food intake impacts health status through specific biological markers, a critical aspect for fully understanding the connections between dietary patterns and health outcomes.

However, these research gaps precisely necessitate more detailed and comprehensive analysis. Biomarkers, especially biochemical indicators in the blood, are powerful tools for assessing the relationship between ready-to-eat food intake and chronic disease risks, reflecting metabolic changes, inflammatory states, and other health-related physiological processes[13, 14]. Despite the challenges, biomarkers are indispensable for revealing potential pathological mechanisms and identifying early health risk indicators.

The study utilizes the extensive data of the NHANES database to conduct a thorough exploration of the relationship between ready-to-eat food consumption frequency and specific chronic diseases, particularly through blood biochemical indicators. By analyzing the associations between ready-to-eat food consumption frequency, chronic diseases, and biochemical indicators, we aim to uncover the underlying mechanisms of these consumption patterns and provide evidence-based recommendations for public health policy and health guidance. This approach aims not only to bridge existing research gaps but also to offer a more comprehensive perspective on the complex relationships between ready-to-eat food consumption and chronic diseases.

## 2. Methods

### 2.1 Data Collection

The study uses data from the National Health and Nutrition Examination Survey (NHANES), managed by the Centers for Disease Control and Prevention (CDC), which periodically collects and analyzes data on the health and nutritional status of United States. Data collected from 2010 to 2020 encompass participants of diverse regions, ages, genders, and ethnicities from across the U.S. The dataset includes detailed dietary frequency questionnaires, health assessments, and biochemical indicator tests. Sample selection criteria included adults aged 18 to 80 years with complete dietary and biochemical indicator data, excluding pregnant or breastfeeding women, those with severe chronic diseases, and individuals with specific drug treatment histories. Ultimately, the study sample comprised 79,589 participants.

### 2.2 Indicators Definition

Ready-to-eat food consumption frequency was determined by analyzing NHANES's 24-hour dietary recall questionnaire. Consumption frequency for each food item was quantified based on self-reported data from participants over the past 30 days. The study investigated 12 chronic diseases, including diabetes, coronary heart disease, hypertension, asthma, angina, renal failure, apoplexy, thyroid disease, liver disease, kidney stones, and heart failure, sourced from the NHANES database. The 28 selected blood biochemical indicators, including white blood cell count (WBC), red blood cell count (RBC), and hemoglobin (Hb) among others (Table 1), were chosen for their ability to reflect metabolic and nutritional status, and chronic disease risk.

**Table 1 Blood Biochemical Indicators**

| Blood Biochemical Indicators | Abbreviation |
|---|---|
| White blood cell count (1000 cells per microliter) | WBC |
| Red blood cell count (million cells per microliter) | RBC |
| Hemoglobin concentration (grams per deciliter) | Hb |
| Mean cell volume (femtoliters) | MCV |
| Mean cell hemoglobin (picograms) | MCH |
| Platelet count (1000 cells per microliter) | Platelet Count |
| Mean platelet volume (femtoliters) | MPV |
| Lymphocyte percentage (%) | Lymphocyte % |
| Monocyte count (1000 cells per microliter) | Monocyte Count |
| Neutrophil count (1000 cells per microliter) | Neutrophil Count |
| Eosinophil count (1000 cells per microliter) | Eosinophil Count |
| Basophil count (1000 cells per microliter) | Basophil Count |
| Glycated hemoglobin percentage (%) | HbA1c % |
| Direct HDL cholesterol concentration (millimoles per liter) | Direct HDL-C |
| Total cholesterol concentration (millimoles per liter) | Total Cholesterol |
| Albumin concentration (grams per deciliter) | Albumin |
| Creatinine concentration (moles per liter) | Creatinine |
| Blood urea nitrogen concentration (millimoles per liter) | BUN |
| Gamma-glutamyl transferase (U/L) | GGT |
| Alkaline phosphatase (U/L) | ALP |
| Alanine aminotransferase (ALT) (U/L) | ALT |
| Uric acid concentration (micromoles per liter) | Uric Acid |
| Total bilirubin concentration (micromoles per liter) | Total Bilirubin |
| Triglyceride concentration (millimoles per liter) | Triglycerides |
| Total protein concentration (grams per deciliter) | Total Protein |
| Globulin concentration (grams per deciliter) | Globulin |
| Aspartate aminotransferase (AST) (U/L) | AST |
| Lactate dehydrogenase (U/L) | LDH |

### 2.3 Correlation Analysis

Box plots explore the distribution and relationships between ready-to-eat food consumption frequency and various chronic diseases. Heatmaps reveal the correlation strength between ready-to-eat food consumption frequency and 28 biochemical indicators. In the heatmaps, color intensity indicates correlation strength, helping identify indicators closely related to food consumption frequency.

### 2.4 Mendelian Randomization (MR) Analysis

Genetic variations associated with the biochemical indicators most strongly correlated to ready-to-eat food consumption frequency serve as instrumental variables. MR analysis explores the causal relationships between these biochemical indicators and chronic diseases. Public genetic databases offer single nucleotide polymorphism (SNP) data to evaluate the associations between genetic variations and targeted biochemical indicators. Subsequently, two-stage least squares regression (2SLS) estimates the impact of these variables on chronic disease risk, ensuring the scientific validity and effectiveness of the causal inference.

### 2.5 Statistical Analysis

Descriptive statistics summarize baseline

characteristics, presenting continuous variables as means ± standard deviations, and categorical variables as frequencies and percentages. The relationships between the consumption frequency of ready-to-eat foods, chronic diseases, and biochemical indicators are analyzed using Spearman rank correlation coefficients. Box plots depict the distribution of ready-to-eat food consumption frequencies across various disease states, while the Wilcoxon test compares consumption differences under differing disease conditions. Heatmaps show the strength of the correlation between the consumption frequency of ready-to-eat foods and blood biochemical indicators. R software was used for all analysis.

### 2.6 Data Availability Statement

The NHANES database used in this study is publicly available, ensuring data transparency and reproducibility. Data are accessible via the official Centers for Disease Control and Prevention (CDC) website. Data processing and analysis codes are available upon reasonable request.

## 3.Results

### 3.1 Correlation of ready-to-eat foods and chronic diseases.

Box plots show significant correlations between the frequency of ready-to-eat food consumption and eight chronic diseases ($P$<0.05).These include diabetes ($P$<0.001), coronary heart disease ($P$<0.001), hypertension ($P$<0.001), asthma ($P$=0.0014), angina ($P$<0.001), renal failure ($P$=0.0024), apoplexy ($P$<0.001), and thyroid disease ($P$=0.037) (Figure 1A-H). **Figure 1.**

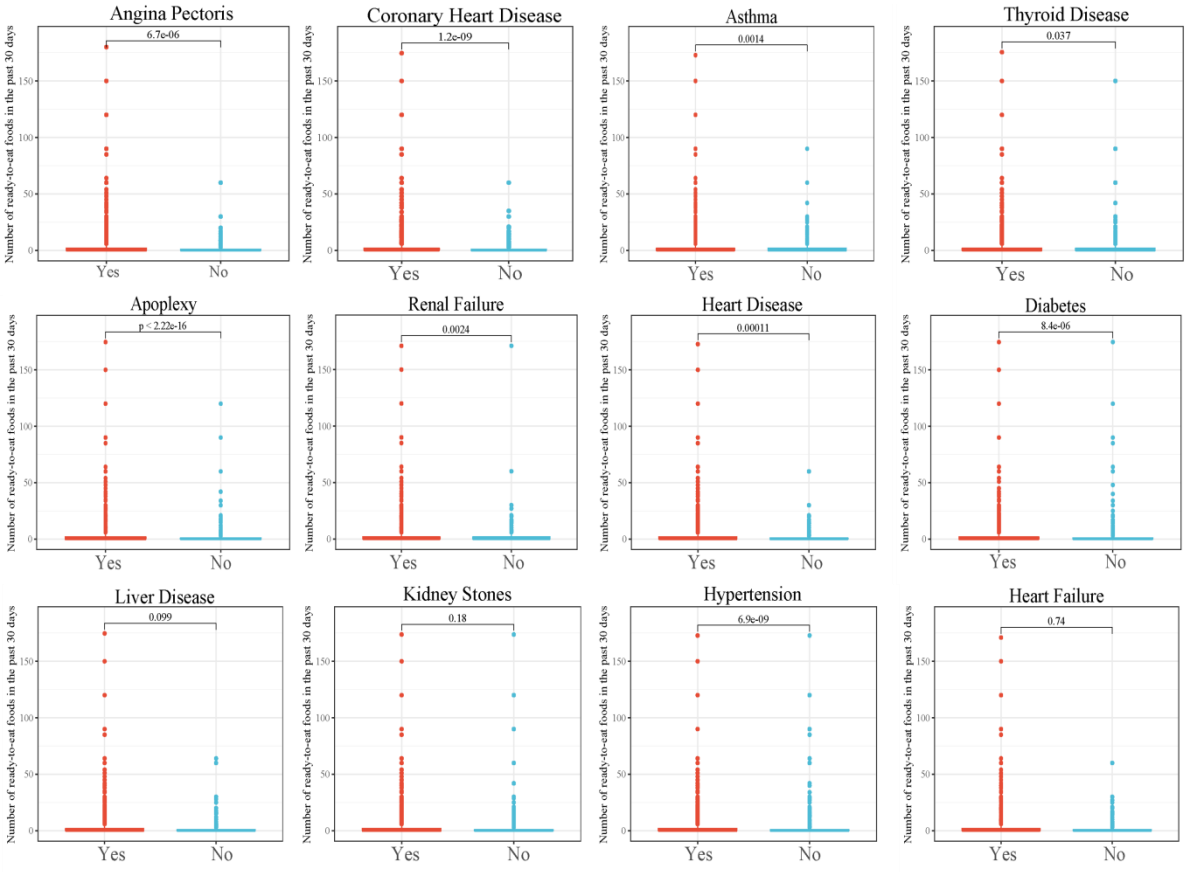


**Figure 1 Correlation between ready-to-eat food consumption frequency and chronic diseases.**

Box plots depict the relationship between the frequency of ready-to-eat food consumption and the incidence of diabetes, coronary heart disease, hypertension, asthma, angina, renal failure, apoplexy, and thyroid disease.**3.2 Correlation of ready-to-eat foods and Blood Indicators**

Heatmaps indicate a strong correlation between the consumption frequency of ready-to-eat foods and Hb levels ($P$<0.001, r=0.06), suggesting that increased consumption is associated with higher

Hb levels. Other indicators including total cholesterol, low-density lipoprotein, and blood glucose exhibited correlations (r= -0.03 to 0.04), albeit less significant than those for Hb (Figure 2A). Further regression analysis showed a significant correlation between Hb levels and ready-to-eat food consumption (P<0.05) (Figure 2B).

**Figure 2**

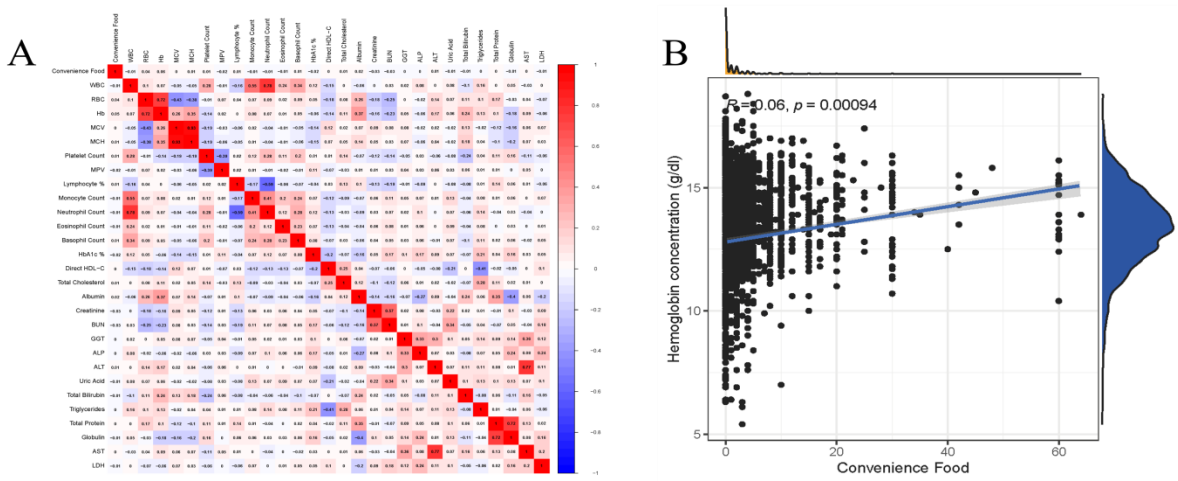


**Figure 2 Correlation between ready-to-eat food consumption frequency and blood indicators.**

**A.** Heatmap illustrating the relationship between ready-to-eat food consumption frequency and blood indicators. **B.** Correlation analysis.

### 3.3 Relationship Between Hb levels and Disease

MR analysis reveals that Hb levels have a positive causal relationship with diabetes, coronary heart disease, and hypertension (estimated causal effect coefficients of 1.005, 1.003, and 1.012 respectively, with 95%CI of [1.001, 1.009], [1.001, 1.005], and [1.002, 1.023]; *P*<0.05) (Figure 3A-C), suggesting that higher Hb levels are associated with an increased risk of these diseases. Conversely, Hb levels show a negative causal relationship with asthma (estimated causal effect coefficient of 0.993, with a 95% confidence interval of [0.987, 0.999]; *P*<0.05) (Figure 3D), implying that higher Hb levels may be associated with a lower risk of asthma. No causal relationships were found between Hb levels and angina, renal failure, apoplexy, or thyroid disease, as shown in Figure 4A-D.

**Figure 3**

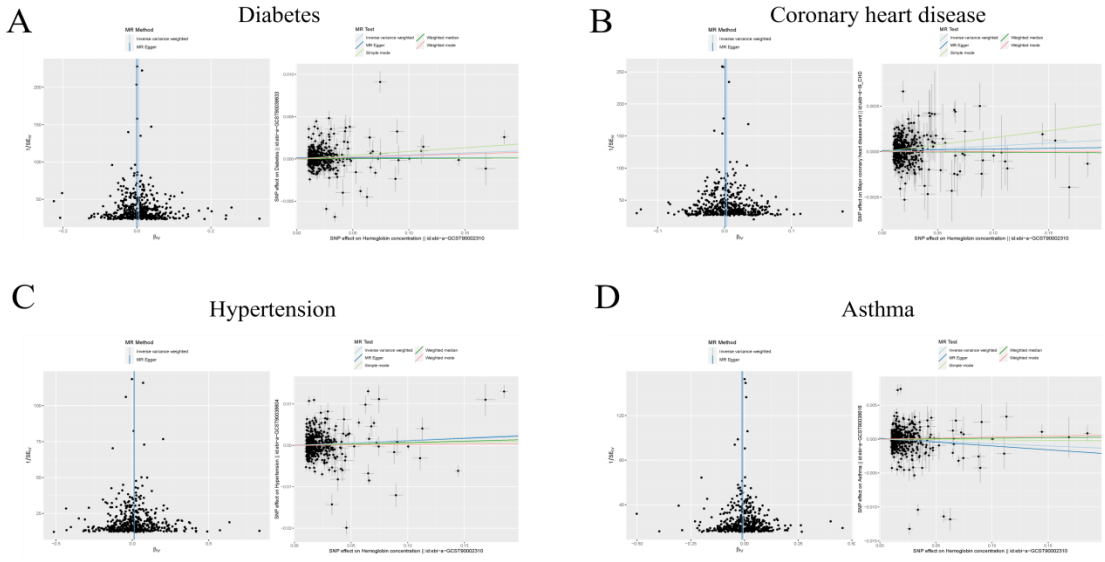

**Figure 3 Relationships between Hb levels and diseases.**

**A.** Relationship between Hb levels and diabetes. **B.** Relationship between Hb levels and coronary heart disease. **C.** Relationship between Hb levels and hypertension. **D.** Relationship between Hb levels and asthma.

**Figure4**

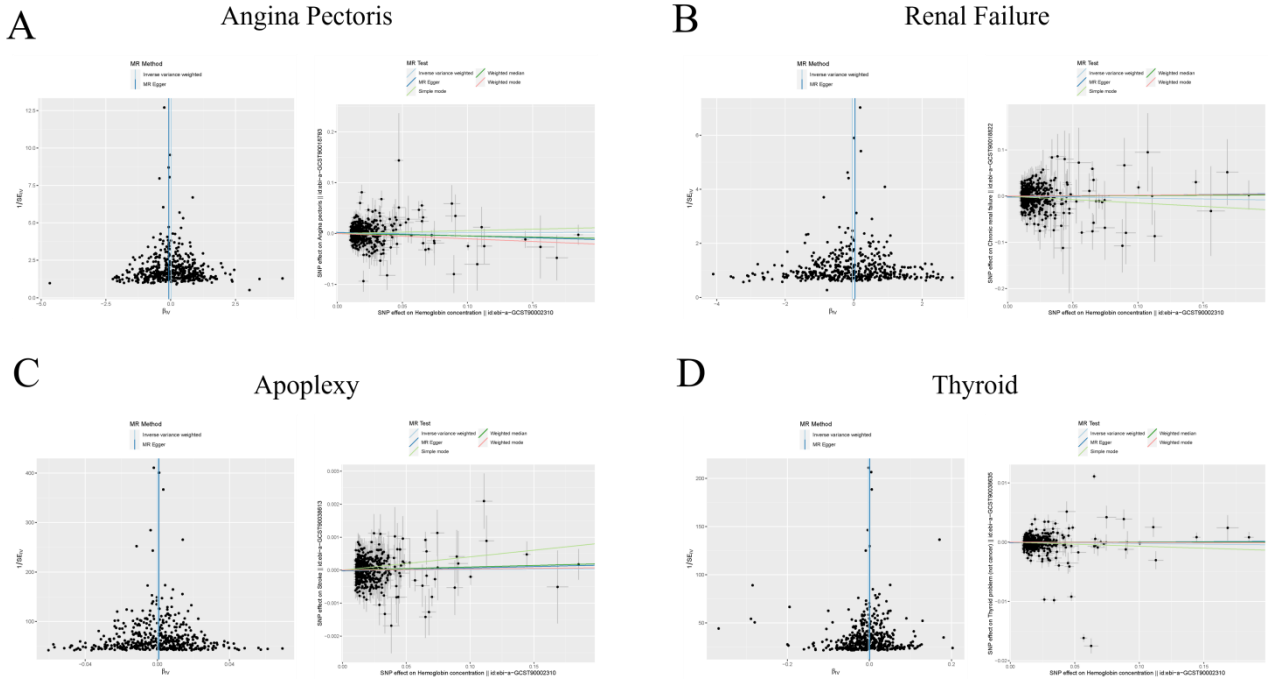


**Figure 4 Relationships between Hb levels and diseases.**

**A.** Relationship between Hb levels and angina. **B.** Relationship between Hb levels and renal failure. **C.** Relationship between Hb levels and apoplexy. **D**. Relationship between Hb levels and thyroid.

**Discission**

This study investigated the correlations between the consumption frequency of ready-to-eat foods, chronic diseases, and blood biochemical indicators. The study revealed both the link between the frequency of ready-to-eat food consumption and chronic disease risk, and highlighted Hb levels as a key biomarker connecting dietary habits to health outcomes. Notably, MR analysis uncovered positive causal relationships between elevated Hb levels and diseases such as diabetes, coronary heart disease, and hypertension, as well as a negative causal relationship with asthma. These findings emphasize that the frequency of ready-to-eat food consumption directly affects biomarkers, influencing health risks and laying the groundwork for further research.

The study identified correlations between the consumption of ready-to-eat foods and a range of chronic diseases, such as diabetes, coronary heart disease, hypertension, asthma, angina, renal failure, apoplexy, and thyroid disease. These findings resonate with extensive evidence from previous epidemiological studies, demonstrating a significant link between the consumption of ready-to-eat foods and various chronic health conditions. Notably, in developing countries, the growing prevalence of these foods is raising concerns over associated risk factors like heavy metal contamination, decreased natural microbiome diversity, and the consumption of highly processed foods typical in Western diets. Such factors could collectively influence the human gut microbiome ecosystem, potentially leading to increased rates of metabolic and immune diseases, and thus impacting public health[15]. Additionally, the marked increase in the consumption of processed and ultra-processed foods, and their association with non-communicable diseases, continues to be a significant research focus[16]. A Study[17] exploring the biological mechanisms by which ultra-processed foods influence cardiovascular

health provide crucial insights, indicating that these effects extend beyond the impact of individual nutrients on cardiac metabolic health.

Our study expands upon existing research by confirming the correlation between ready-to-eat food consumption and chronic diseases, and identifying Hb levels as a biomarker linking the frequency of ready-to-eat food consumption to chronic disease risk. This discovery is an important addition to current knowledge, highlighting that the frequency of ready-to-eat food consumption is not only directly related to the risk of chronic diseases but may also impact individual health status by altering hemoglobin, a key biomarker. Our findings indicate that an increase in the consumption frequency of ready-to-eat foods is significantly associated with elevated HB levels, a phenomenon that may reflect the effects of high iron content or high caloric components in ready-to-eat foods on an individual's metabolic status. Further analyses and literature reviews suggest that the intake of highly processed foods is closely related to changes in blood parameters, which could further impact health status. For instance, some studies have pointed out that high iron intake is associated with increased oxidative stress, while high caloric intake may lead to weight gain and insulin resistance, both critical factors in the development of chronic diseases[18, 19]. Our results are consistent with these findings, further confirming the potential link between the frequency of ready-to-eat food intake, Hb levels, and the risk of chronic diseases.

Furthermore, the study utilized MR analysis to reveal that the consumption frequency of ready-to-eat foods, by influencing Hb levels, shows a positive causal relationship with diabetes, coronary heart disease, and hypertension. This suggests that elevated Hb levels could be a significant pathway through which increased consumption of ready-to-eat foods leads to higher risks of these diseases. Such elevations may reflect the cumulative metabolic impact of the high energy, high fat, high salt, and other detrimental components typical of ready-to-eat foods, including increased inflammation, metabolic disorders, and imbalances in oxygenation and nutrition. For instance, high energy and sugar intake may lead to insulin resistance and an increased risk of diabetes, while high salt intake is closely linked to hypertension[20]. On the other hand, ready-to-eat foods may lack essential micronutrients and vitamins, further exacerbating the issue of nutritional imbalance. Conversely, for asthma, we identified a negative causal relationship, which may reflect different biological mechanisms or disease-specific responses, such as certain ingredients potentially suppressing inflammation pathways associated with asthma to some extent. Although the specific roles of these mechanisms require further study for clarification, our analysis provides preliminary evidence of the biological links between the consumption of ready-to-eat foods and health risks, underscoring the importance of understanding and improving dietary habits in the management of chronic diseases.

Although our study offers novel insights into the correlation between the consumption of ready-to-eat foods and chronic diseases, it also has several limitations. Firstly, despite MR analysis being a potent tool for assessing causal relationships, it relies on the validity of the chosen instrumental variables. If these variables are confounded with unidentifiable factors or are associated with other diseases, this may compromise the accuracy of causal inference. Secondly, our research primarily focuses on the relationship between the frequency of consumption of ready-to-eat foods and specific chronic diseases and hemoglobin levels, potentially overlooking the impact of the type of ready-to-eat foods, their nutritional quality, and other lifestyle factors. Future research should explore the effects of different types of ready-to-eat foods on health, considering a broader range of individual behaviors and environmental factors.

In summary, our study provides preliminary evidence of the potential correlation and causal link between the frequency of consumption of ready-to-eat foods and the development of chronic diseases. These findings underscore the importance of considering the type and frequency of food consumption in the formulation of public health policies, and offer new directions and perspectives for future research.

**Author Contribution**

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

**Conflict of Interest**

All authors declare no competing interests.

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