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Nutritional Patterns and Dietary Strategies across Diet-Related Diseases: A Visual Analysis Approach

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Abstract. Chronic health conditions such as hypertension, obesity, diabetes, and kidney disease are increasingly prevalent globally, with many of them having interconnected dietary factors. This study examines the potential roles of several nutrients in these illnesses as well as the ways in which dietary patterns may contribute to their development. By analyzing data visually, the study identifies common risk factors such as high sodium, too much energy intake, and low fiber. At the same time, the effects of nutrients like protein and fat appear to vary depending on the condition. For example, while protein can support muscle maintenance during weight loss, too much of it may affect insulin sensitivity or put stress on the kidneys. Fat intake may play a role in skin-related conditions, and sodium remains especially important in managing blood pressure and kidney health. The findings point to the value of creating more personalized nutrition plans based on the specific needs of each condition.

Keywords: Nutritional Patterns, Dietary Strategies, Visual Data Analysis, Chronic Conditions

1. Introduction

Diet-related diseases are on the rise globally, with conditions like hypertension, diabetes, and obesity placing a growing strain on public health. Consumption of ultra-processed foods has surged globally in recent decades, a trend that has coincided with rising rates of non-communicable diseases [1]. According to the National Heart, Lung, and Blood Institute, Americans' poor diet drives $50 billion in annual healthcare costs [2]. As a result, diet-related conditions can make daily life more difficult for individuals and add pressure to healthcare systems by increasing hospital stays, medication needs, and demand for long-term care. In recent years, research linking dietary patterns with multimorbidity has grown substantially. One recent study by Mao et al. identified specific dietary patterns among older adults that were linked to reduced risks of co-occurring cardiometabolic, cognitive, and sleep disorders, underscoring the potential of holistic dietary strategies in managing multiple chronic conditions [3]. This review takes a closer look at those patterns through visual data analysis and offers practical dietary strategies that reflect what the patterns reveal. By highlighting the shared nutritional patterns across different diet-related diseases, it also offers insights that could help shape future strategies for preventing chronic illness, support the development of public health policies, and suggest ways to address common dietary challenges.

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2. Nutritional features of diet-related diseases

Figure 1 illustrates that chronic diet-related conditions such as hypertension, heart disease, type 2 diabetes, and weight gain have frequently been observed to co-occur. These overlapping disease clusters often share common underlying dietary patterns. Diets high in energy-dense foods, including processed meats and sugar-sweetened beverages, have been linked to an increased risk of obesity and related chronic conditions [4]. For protein, while higher overall intake appears beneficial for blood pressure reduction, animal-based protein consumption in excess may negatively impact metabolic health. Supplementing with soluble dietary fiber has been shown to significantly improve glycemic control in adults with type 2 diabetes. According to meta-analysis results, there are notable decreases in critical indicators such as glycated hemoglobin (HbA1c), fasting glucose levels, insulin resistance, and postprandial blood glucose when compared with control diets [5]. Sodium reduction remains a cornerstone of hypertension interventions; however, overly restrictive sodium intake has been linked to worsening insulin sensitivity, highlighting the need for balance. The common nutritional aspects highlight the effectiveness of dietary patterns like the Dietary Approaches to Stop Hypertension (DASH) and the Mediterranean diet. These diets, known for moderate protein intake, sufficient fiber, regulated sodium levels, and healthy fats, are beneficial in managing multiple co-occurring health conditions.

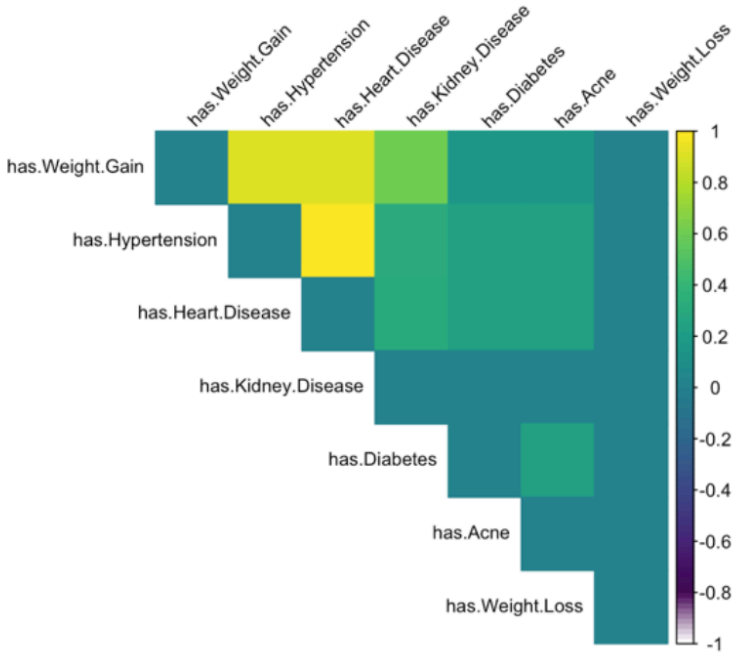


Figure 1. Disease co-occurence

3. Nutrient-specific analysis

3.1. Protein intake across diseases

A nutrient-specific analysis across various diet-related diseases reveals distinct patterns that may inform tailored dietary strategies. Figure 2 displaying protein intake across conditions demonstrates considerable variation in both median levels and overall distribution. Among all the groups, individuals classified under weight gain exhibit the highest protein intake, with a wide interquartile range and numerous outliers. This distribution suggests a high degree of variability, potentially

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indicating that some individuals in this group consume significantly more protein, either due to increased caloric intake or dietary choices targeting muscle gain or satiety. This elevated protein level stands in sharp contrast to the kidney disease group, where protein intake is markedly lower. Both the median and the spread are compressed, suggesting that individuals with kidney disease maintain tighter control over protein consumption, likely due to medical dietary guidance aimed at reducing renal burden.

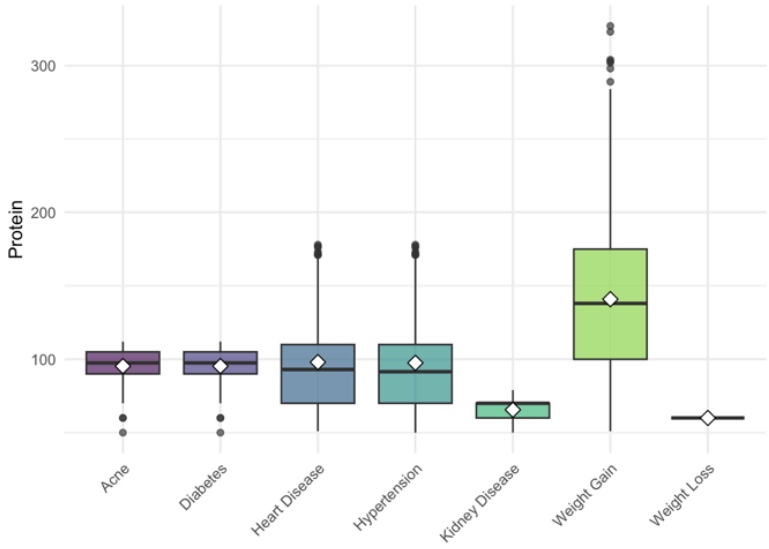


Figure 2. Protein intake by disease

Individuals with hypertension and heart disease show moderately elevated protein levels, although they remain well below the values seen in the weight gain group. These distributions suggest that while protein is not highly restricted, it is not a central focus in the dietary management of these conditions. The acne and diabetes groups show similar median protein values, indicating no particularly distinctive pattern in their protein consumption. Interestingly, the weight loss group demonstrates the lowest median and least variable protein intake. This narrow distribution could reflect structured, calorie-controlled diets, where protein consumption is minimized or carefully portioned.

3.2. The role of nutrients in disease differentiation

To further explore the role of nutrients in disease differentiation, Figure 3 offers valuable insights. Each disease is associated with a unique profile of influential dietary components. The heatmap suggests a modest role of fat in acne, yet previous evidence highlights important pathways through which fat may influence sebaceous activity. Riley et al. demonstrate that within days, dietary fat can be rapidly incorporated into skin tissues, including sebaceous glands [6]. After mice were switched to a high-fat diet, dietary triglycerides accumulated in both the epidermis and dermal white adipose tissue and persisted for weeks. This incorporation was associated with significant changes in lipid composition in sebocytes and keratinocytes, suggesting that fat intake directly modulates skin lipid metabolism and sebum-related cell function. Furthermore, lipidomic analysis shows that sebaceous gland cells take up nutrients from the bloodstream and increase their synthetic activity when enough fat is available. This finding suggests that dietary fat promotes sebum production by stimulating lipid synthesis in sebocytes.

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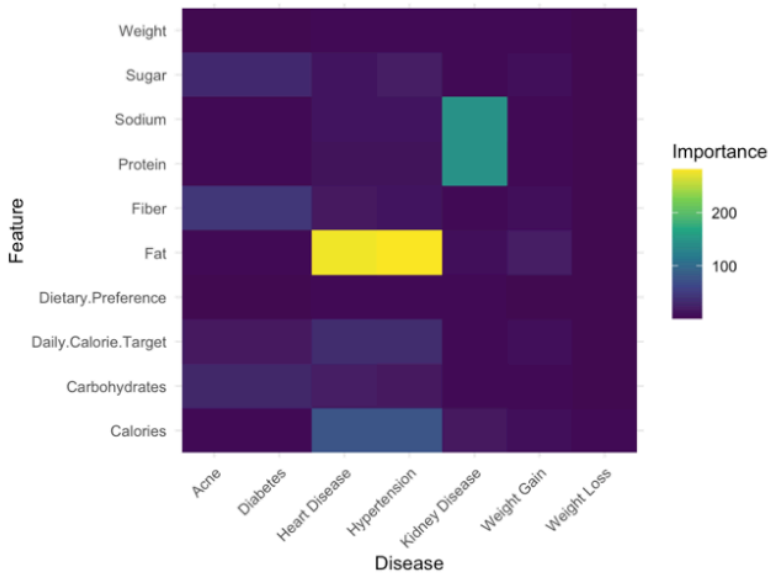


Figure 3. Feature importance heatmap by disease

Sodium holds the highest predictive value for kidney disease, underscoring its critical role in fluid retention, hypertension, and renal function. Excessive sodium intake contributes to glomerular hyperfiltration, proteinuria, and extracellular fluid expansion, all of which accelerate the deterioration of renal function. It also stimulates pro-inflammatory and fibrotic pathways, increases oxidative stress, and triggers sympathetic nervous system activity including mechanisms that compound renal injury in CKD patients [7]. However, sodium intake should not fall below physiological needs, as excessive restriction may impair insulin sensitivity. Evidence indicates that very low salt intake activates the renin–angiotensin–aldosterone system (RAAS), resulting in elevated aldosterone levels, which impair glucose-stimulated insulin secretion (GSIS) and reduce insulin sensitivity. Studies in both humans and animal models have shown that aldosterone disrupts beta-cell function and insulin signaling, even in the absence of changes in body weight. Furthermore, low sodium intake can increase sympathetic nervous system (SNS) activity, as reflected by higher norepinephrine levels in urine, which has been independently associated with insulin resistance. These findings suggest that while moderate sodium reduction benefits cardiovascular health, overly strict restriction may disrupt hormonal and neural mechanisms essential for glucose homeostasis [8].

Adequate but not excessive protein intake is important for preserving muscle during weight loss. Sufficient dietary protein, particularly when evenly distributed throughout the day, has been shown to help minimize the loss of lean body mass during caloric restriction. This is especially relevant in individuals undergoing weight-loss therapy, where muscle preservation is essential for maintaining metabolic rate and physical function. However, evidence also indicates that consuming protein beyond optimal levels may produce adverse metabolic effects. Smith et al. demonstrated that in postmenopausal women, high protein intake during a hypocaloric diet eliminated the improvement in muscle insulin sensitivity typically observed after weight loss [9]. Despite similar weight reduction across groups, only those on the standard-protein diet experienced enhanced insulin action. Furthermore, Cava, Yeat, and Mittendorfer reviewed multiple cross-sectional and epidemiologic studies suggesting that excessive protein consumption is associated with increased risk of insulin resistance and the development of type 2 diabetes [10]. These findings suggest that while protein is a critical nutrient for muscle maintenance, its intake must be carefully balanced to

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avoid compromising glucose metabolism. Strategic dietary planning should therefore provide enough protein during weight loss interventions while avoiding excess to support musculoskeletal and metabolic health.

Weight and calorie-related variables, such as daily calorie targets and total energy intake, show moderate importance in conditions like hypertension, weight gain, and weight loss. These findings indicate the overarching influence of energy balance in the progression or prevention of metabolic disorders. Fiber and carbohydrates, on the other hand, demonstrate relatively low importance across most conditions in the heatmap, which may indicate their limited role in distinguishing between disease types within this dataset, or that their influence is more context dependent.

Overall, these patterns reinforce the concept that dietary interventions should be condition specific. While protein intake may support muscle maintenance in weight loss or strength goals, it must be limited in kidney-related conditions to prevent further renal deterioration. Reducing fat intake could be emphasized in dermatological conditions like acne, whereas sodium control remains essential in kidney disease. The importance of energy balance, reflected in features like total calories and body weight, also suggests that macronutrient ratios alone are insufficient; overall dietary patterns and quantities matter significantly in disease outcomes.

4. Dietary intervention strategies

The identification of shared and disease-specific nutritional patterns provides a practical foundation for developing targeted dietary interventions. For individuals with kidney disease, sodium restriction should be a primary focus, aiming to prevent fluid overload and reduce glomerular pressure. However, sodium intake should not fall below physiological needs, as excessive restriction may impair insulin sensitivity. In contrast, fat reduction should be prioritized in populations with acne or related dermatological conditions, given its role in modulating sebaceous lipid metabolism. For individuals with weight gain or obesity, interventions should emphasize total energy control while ensuring that protein intake supports muscle retention without exceeding metabolic tolerance. There is always a greater chance of positive results when the intervention is customized to the disease rather than using general dietary recommendations. Instead of concentrating only on specific macronutrients, effective solutions should consider the diet's overall composition, meal timing, and nutritional interactions.

5. Conclusion

This review examines the shared and distinct nutritional features of these conditions and explores how specific nutrients relate to disease presence and progression. Through visual data analysis, patterns emerged that emphasized the importance of dietary balance, particularly regarding protein, fat, sodium, and total energy intake. Findings suggest that while certain nutrients may benefit one condition, they could be harmful in another, highlighting the need for condition-specific dietary strategies. For example, moderate protein intake supports muscle preservation during weight loss but must be carefully managed in individuals with kidney disease. Similarly, fat reduction may be especially important in dermatological conditions like acne, whereas sodium control remains central to managing blood pressure and renal function. Future dietary guidelines should be customized to the actual physiological requirements and risks of each condition rather than depending on general guidelines. This review backs a more individualized approach to food planning that is based on knowledge of how nutrients interact in various disease scenarios as well as scientific facts.

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This review offers meaningful insights into the nutritional patterns associated with diet-related diseases, but several limitations should be considered. One of the main concerns is the relatively small sample size, which may reduce the ability to generalize the findings to a broader population. Another limitation is that the data used in this study were cross-sectional, meaning they reflect a single point in time. This makes it hard to tell whether certain dietary patterns contributed to the development of disease, or whether individuals changed their eating habits after being diagnosed. Long-term studies that follow individuals over time would help provide clearer answers. Additionally, the way diseases were identified may not have been based on clinical diagnoses. When people report their own conditions, there is always a chance of misunderstanding or misclassification. This could affect the accuracy of how different diseases are linked to specific dietary patterns. However, the review identifies significant patterns that can inform more individualized dietary advice. It serves as further evidence that dietary plans that are effective must be customized to meet the unique requirements of each condition. Larger, more thorough datasets that incorporate clinical data and lifestyle context would be beneficial for future studies. A more comprehensive picture of how nutrition affects health over time would result from this.

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