SRI VENKATESWARA INTERNSHIP PROGRAM FOR RESEARCH IN ACADEMICS (SRI-VIPRA)

SRI-VIPRA

Project Report of 2025

SVP-2512: ASSESSMENT OF BIOMARKERS OF CHRONIC INFLAMMATION AND PROPHYLACTIC MEASURES

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SRIVIPRA PROJECT 2025

SVP-2512

Title: Assessment of Biomarkers of Chronic Inflammation and Prophylactic Measures

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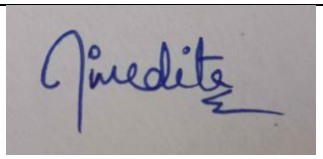
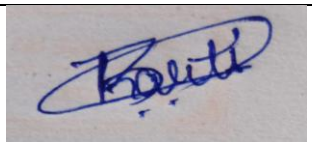
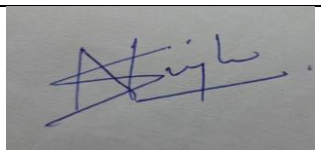
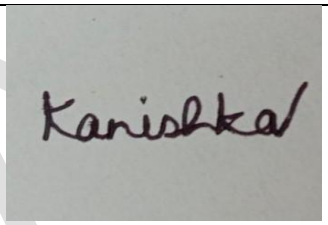
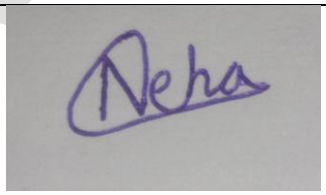
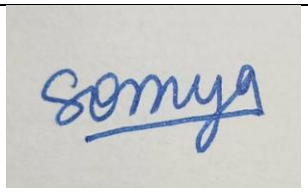
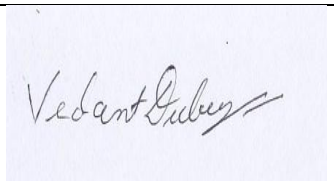
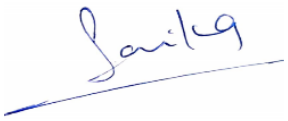
2		Nivedita Kalia	1223044	B.Sc. (Hons.) Biochemistry Sem-V	
3		Bharti Kaswan	1323019	B.Sc. (Hons.) Biological sciences Sem-V	

4		Niharika	1323047	B.Sc. (Hons.) Biological sciences Sem-V	
5		Kanishka	1224027	B.Sc. (Hons.) Biochemistry Sem-III	
6		Neha Singh	1224041	B.Sc. (Hons.) Biochemistry Sem-III	
7		Somya Wassan	1224047	B.Sc. (Hons.) Biochemistry Sem-III	
8		Vedant Dubey	1124069	B.Sc. (prog.) Life Sciences Sem-III	

Signature of Mentor

Certificate of Originality

This is to certify that the aforementioned students from Sri Venkateswara College have participated in the summer project SVP- 2512 titled "**Assessment of Biomarkers of Chronic Inflammation and Prophylactic Measures"**. The participants have carried out the research project work under my guidance and supervision from 1st July, 2025 to 30th September 2025. The work carried out is original and carried out in an offline mode.



Signature of Mentor

Acknowledgements

With immense pleasure and pride, we share the report of Sri-Vipra Project SVP-2512 titled- "Assessment of Biomarkers of Chronic Inflammation and Prophylactic Measures". We would like to express our deepest gratitude for everyone who worked tirelessly for successful completion of this project. Our deepest gratitude to Sri Venkateswara College for hosting the Sri-Vipra program and encouraging young students like us to gain research experience. We would like to thank our esteemed Principal, Prof. Vajala Ravi for providing us the opportunity to undertake this internship. Our sincere gratitude to our mentor, Dr. Sarika Yadav for her support and guidance throughout the course of this project. This journey has been a valuable learning experience due to her unwavering support, guidance, and mentorship. Her expertise, encouragement, and willingness to share her expertise and knowledge has been instrumental in our growth as a researcher. We would also like to extend our appreciation to coordinators of the Sri-Vipra internship program. Finally, we express our gratitude to the Almighty for countless blessings, knowledge, and opportunities.

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Introduction

Inflammation is the body's natural defense mechanism which occurs when any foreign particle, like pathogens, or dust particles, enters our system leading to an active immune response. If this immune response lasts for a few days to weeks, it is called Acute inflammation, which is considered less harmful as it is followed by the complete healing of the affected tissue. Whereas, Chronic inflammation refers to a long-term inflammatory response which could last for months or years, caused by a long-term persistent exposure to irritants or failure of the immune system to eliminate the causative agent. As the inflammation lasts, it causes damage to the healthy cells and tissues and contributes further to disease progression.

Unlike acute inflammation, which is characterized by immediate and noticeable symptoms such as redness, heat, swelling, and pain, chronic inflammation often presents with more subtle and systemic manifestations. Common symptoms of chronic inflammation include persistent fatigue, low-grade fever, and generalized body pain or stiffness, particularly in the joints and muscles.

Chronic inflammation develops when the immune response fails to resolve and remains active over long periods. Macrophages play a central role: pro-inflammatory M1 macrophages release cytokines such as TNF-α (Tumor Necrosis Factor-α) and IL-6 (Interleukin-6) that drive tissue damage, while M2 macrophages promote repair. Neutrophils may persist at the site and release reactive oxygen species, prolonging injury. T lymphocytes, especially Th17 cells, further amplify inflammation, while weakened regulation by T regulatory cells prevents resolution. Together with dendritic and B cells, these immune players form a self-sustaining cycle of immune activation that underlies many chronic inflammatory disorders.

- **Type 2 Diabetes:** It is closely linked to chronic inflammation, with numerous studies showing that chronic low grade inflammation contributes to insulin resistance and pancreatic beta cell dysfunction, which are central to the development and progression of the disease.
- **Rheumatoid Arthritis:** It is an autoimmune condition causing chronic synovitis, pain, swelling, and stiffness. Over time, the persistent inflammatory process leads to progressive joint damage and deformities.
- **Inflammatory Bowel Disease:** This disease includes Crohn's disease and ulcerative colitis, characterized by persistent inflammation of the gastrointestinal tract, resulting in recurrent abdominal pain, diarrhea, and weight loss.
- **Atherosclerosis:** This is a vascular disorder in which chronic inflammation of the arterial walls occurs in response to endothelial injury and lipid accumulation.
- **Tuberculosis:** Chronic infections such as tuberculosis is caused by Mycobacterium tuberculosis which also exemplify prolonged inflammatory responses. It is a persistent infection that leads to the formation of granulomas, which are aggregates of macrophages, epithelioid cells, and lymphocytes

that attempt to contain the pathogen. This sustained inflammation can result in tissue necrosis, fibrosis, and functional impairment of the affected organs.

- **Chronic Asthma:** The persistent inflammation contributes to airway remodeling, smooth muscle hypertrophy, mucus hypersecretion, and recurrent episodes of wheezing.
- **Hashimoto's Thyroiditis:** It is an autoimmune disorder affecting the thyroid gland, causing glandular fibrosis, atrophy, and hypothyroidism, manifesting clinically as fatigue, weight gain, and cold intolerance.

Biomarkers Introduction

A biomarker is a trait that can be measured and assessed objectively as a sign of typical biological, pathological, or pharmacological reactions to a treatment. Numerous biological specimens, including blood, urine, sputum or saliva, hair, feces, cerebrospinal fluid, and body tissues, can have biomarkers measured in them. Examining inflammatory biomarkers in blood is clearly a standard procedure for clinical diagnosis; however, new trends indicate that, because it is non-invasive, measuring diagnostic biomarkers in novel biological specimens (such as saliva and urine) is gaining popularity. Biomarkers of inflammation may be invasive or non-invasive, each with distinct advantages and limitations.

Types of Biomarkers:

- **Cytokines:** Leukocytes are one of the main sources of cytokines, which are regulatory glycoproteins that are categorized as interleukins (ILs). Their circulating levels serve as useful markers of inflammation because they are produced by activated immune cells and trigger further cytokine release. Because of their connections to immunological activation, mood regulation, and psychosocial stress, important cytokines like IL-6, interferons (IFNs), and tumor necrosis factors (TNFs) are regularly researched.
- **CRP:** C-reactive protein (CRP) is an acute-phase protein produced by the liver in response to inflammation, primarily regulated by interleukin-6 from macrophages and T cells. CRP rises rapidly in infection or tissue damage, sometimes up to 1000 times normal levels, making it a sensitive marker of inflammation. High-sensitivity CRP (hs-CRP) assays detect low-level chronic inflammation and assess cardiovascular risk: <1 mg/L low, 1–3 mg/L average, >3 mg/L high.
- **ESR:** It is a non-specific indicator of inflammation, calculates the rate at which red blood cells settle in anticoagulated blood over the course of an hour. It is impacted by the aggregation of red blood cells, which is primarily facilitated by plasma proteins like fibrinogen, which rise during inflammatory processes and accelerate sedimentation.
- **SAA (Serum Amyloid A):** Acute-phase serum amyloid A proteins (A-SAAs) are rapidly secreted during inflammation and function in cholesterol transport, immune cell recruitment, and extracellular matrix degradation. Like CRP, serum SAA levels rise rapidly in response to inflammation, often more markedly than CRP, and may better reflect disease activity in early inflammatory joint disease.
- **Intercellular Adhesion Molecule 1 (ICAM-1):** It is a cell surface glycoprotein expressed on endothelial cells, epithelial cells, and immune cells. It plays a critical role in inflammation by mediating the adhesion and transmigration of leukocytes from the bloodstream into tissues at sites

of injury or infection. ICAM-1 binds to integrins (e.g., LFA-1 and Mac-1) on leukocytes, facilitating their firm attachment to the endothelium and subsequent extravasation into inflamed tissue.

Inflammation is profoundly influenced by modifiable lifestyle factors, including sleep, dietary habits, and physical activity, as well as by inherent biological variables such as sex and gender. Over the past several decades, a substantial body of research has investigated the bidirectional relationships between these determinants and systemic inflammation. Evidence from epidemiological, clinical, and mechanistic studies consistently demonstrates that alterations in sleep patterns, nutritional quality, and physical activity levels can either exacerbate or mitigate inflammatory processes, thereby influencing susceptibility to a wide spectrum of chronic diseases.

(i) Sleep

Influence of sleep on inflammation

Sleep, inflammation, and immunity are strongly interconnected. Insomnia, a common sleep disorder, is associated with increased risk for inflammatory and infectious diseases, while patients with such conditions frequently present with sleep disturbances. The disease risks linked to chronic inflammation such as depression and Alzheimer's disease mirror those observed with chronic sleep disruption.

Evidence indicates that sleep disturbances alter multiple inflammatory pathways. The secretion of cytokines follows both circadian and sleep-dependent rhythms: pro-inflammatory cytokines (IL-2, IL-6, IL-12, TNFα, IFNγ) peak during nocturnal sleep, whereas anti-inflammatory cytokines such as IL-10 are elevated during the day. Specific sleep stages further modulate these nocturnal cytokine changes.

Influence of inflammation on sleep

The relationship between sleep and inflammation is bidirectional, as modulation of inflammatory processes can in turn influence sleep outcomes. Clinical treatment of insomnia using cognitive behavioural therapy (CBT) or Tai Chi has been shown to reduce inflammatory markers, with effects comparable to those produced by dietary and exercise interventions. In depressed patients with elevated inflammation, pharmacological inhibition of TNF normalised sleep architecture, including reductions in wake after sleep onset, whereas no such improvements were seen in individuals with low baseline inflammation.

(ii) Diet and nutrition

Nutrition is recognized as a modifiable determinant of systemic inflammation and related chronic disease risk. Certain dietary components, such as dietary fiber, antioxidants, and omega-3 fatty acids, are consistently linked to reductions in inflammatory biomarkers, whereas nutrients like saturated fat and sodium are associated with elevated inflammatory activity.

Comparisons of overall dietary patterns reinforce this relationship. Diets characterized as "prudent," with higher intake of fruits, vegetables, legumes, fish, poultry, and whole grains, are associated with lower plasma concentrations of C-reactive protein (CRP) and E-selectin, a marker of endothelial activation. These associations remain significant after controlling for confounders including age, body mass index (BMI), physical activity, smoking, and alcohol intake. In contrast, "Western" dietary patterns, marked by higher consumption of red and processed meats, sweets, desserts, French fries, and refined grains, are positively

associated with CRP and endothelial activation markers, including E-selectin, soluble intercellular adhesion molecule (sICAM-1), and soluble vascular adhesion molecule (sVCAM-1), even after full adjustment.

(iii) Physical inactivity

Physical inactivity contributes to the development of chronic low-grade inflammation, primarily through visceral fat accumulation, and is often accompanied by fatigue and muscle wasting. When combined with comorbidities and disease-specific symptoms, muscle deconditioning and enhanced inflammatory activity impair cardiovascular performance and limit the ability to engage in physical activity (PA), perpetuating a cycle of sedentary behavior and declining health. The health consequences of physical inactivity parallel those of increased abdominal adiposity; however, systemic inflammation resulting from inactivity occurs independently of obesity status.

(iv) Gender and sex

Gender differences in chronic inflammation arise from a complex interplay of biological and sociocultural factors rather than hormones alone. Estrogens suppress NF-κB signaling, reduce pro-inflammatory cytokines, and enhance IL-10 in macrophage-derived TNF-α and IL-1β and promote regulatory T-cell responses, with low levels correlating to higher CRP and IL-6.

Microbiome composition differs by sex and shapes immune tone, with reciprocal effects on hormone metabolism and inflammatory outcomes. Metabolic differences further contribute, since men's visceral fat is more pro-inflammatory compared to women's subcutaneous fat, though menopause shifts fat distribution in women toward visceral depots, raising inflammatory risk. Social and environmental factors such as chronic stress, caregiving roles, occupational exposures, lifestyle habits, and healthcare access intersect with biology to shape inflammatory susceptibility.

Objectives

- **Biomarker Assessment:** Assess serum C-reactive protein (CRP) levels in participants aged 18–25 years as a biomarker of chronic inflammation.

- **Lifestyle Data Collection:** Collect and evaluate lifestyle-related data (dietary and sleeping pattern, physical activity and medical history) of participants through questionnaires.

- **Correlation Analysis:** Analyze correlations between lifestyle factors and CRP concentrations in order to identify potential contributors to chronic inflammation.

- **Prophylactic Implications:** Suggest possible prophylactic measures and lifestyle modifications that may help reduce chronic inflammation and associated disease risks.

Methodology

1. Participants were provided with a consent form thoroughly prepared with a questionnaire based on their dietary pattern, habits, sleep cycle, physical activity and medical history.

- Recording of Dietary Habits
- Recording and Maintenance of Sleep Log
- Recording of Physical Activity
- Collection of Blood Samples and CRP Biomarker Analysis

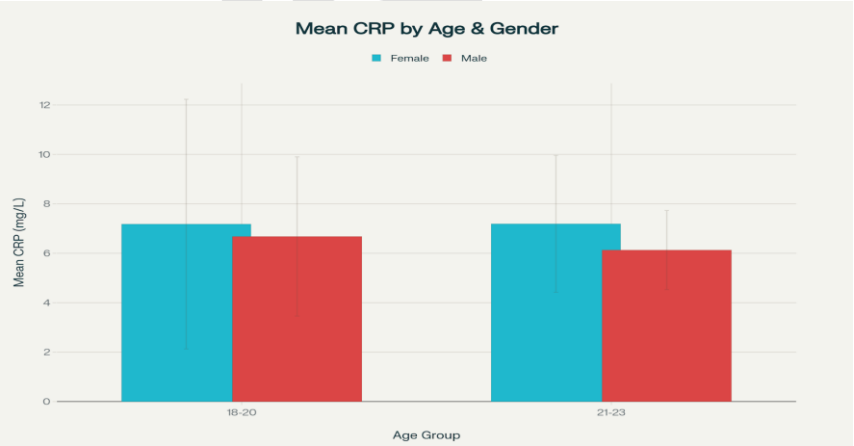
2. Blood samples were collected from participants following standard aseptic procedures. Serum was separated and analyzed for C-reactive protein (CRP) levels using a commercially available CRP detection kit (Turbilatex) according to the manufacturer's instructions. CRP concentrations were determined spectrophotometrically by comparing with the calibrator provided.

3. Data Analysis

- CRP concentrations were compared among groups categorized by sleep pattern (normal vs. sleep-debt), diet type, and physical activity levels.
- Statistical analysis was performed to assess correlations between CRP levels and lifestyle factors (sleep, diet, activity).

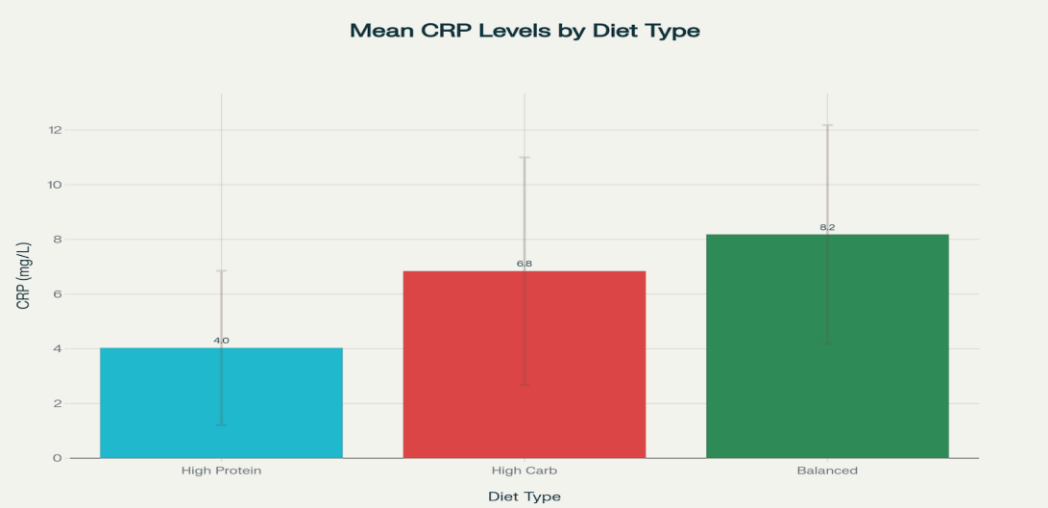
Observation and Result Analysis

1. **CRP Concentration Analysis: Age Group and Gender Effects**



Our analysis reveals minimal significant differences in CRP levels between age groups and genders in this young adult population, contrasting with established patterns observed in older adults. Female participants showed slightly higher mean CRP levels (7.18 mg/L) compared to males (6.59 mg/L), but this difference was not statistically significant (p = 0.687). Similarly, age group differences between 18-20 years (7.00 mg/L) and 21-23 years (6.89 mg/L) were negligible (p = 0.948)

2. CRP Concentration Analysis: Effects of Dietary Composition and Food Source

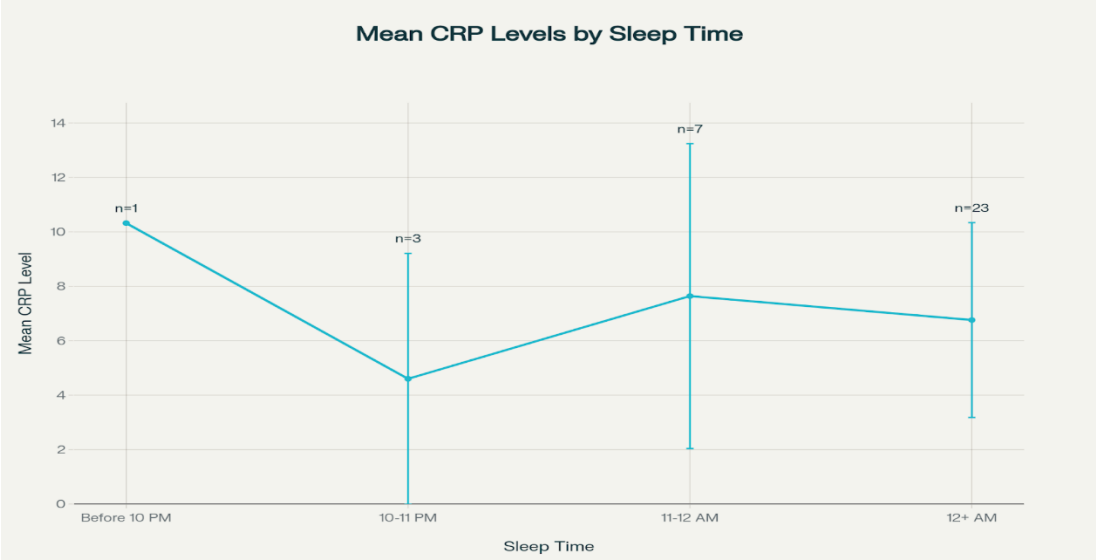


Our analysis reveals a clear macronutrient-dependent gradient in CRP levels, with participants following high-protein diets showing the lowest inflammatory burden (4.03 ± 2.82 mg/L), followed by high-carbohydrate diets (6.84 ± 4.16 mg/L), and balanced diets showing the highest CRP levels (8.18 ± 4.00 mg/L). Surprisingly, participants consuming home-cooked meals had slightly higher mean CRP levels (7.17 mg/L) compared to those eating outside food (5.14 mg/L), though this difference was not statistically significant (p = 0.364).

The data demonstrates a progressive increase in CRP levels across dietary patterns:

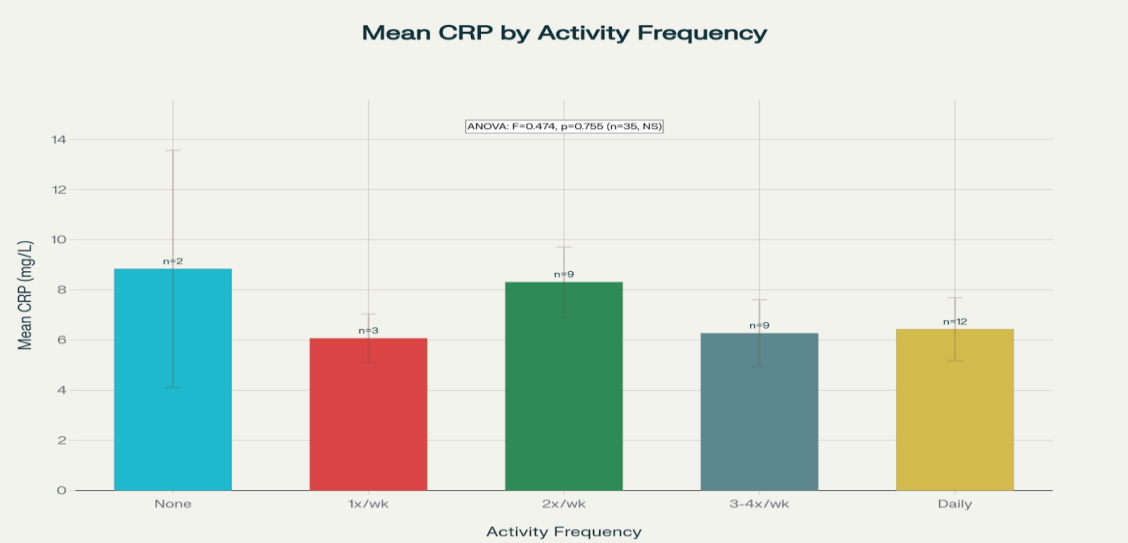
- High Protein → High Carbohydrate → Balanced: 4.03 → 6.84 → 8.18 mg/L
- Total increase from High Protein to Balanced: 4.14 mg/L (103% increase)

3. Sleep Pattern and CRP Concentration: Comprehensive Analysis



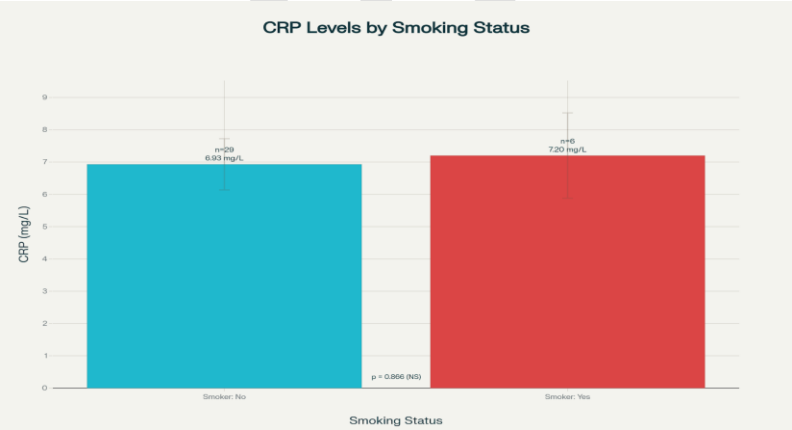
Our analysis reveals unexpected patterns in the sleep-CRP relationship among young adults aged 18-23 years. Participants sleeping 7-8 hours showed the lowest mean CRP levels (5.88 mg/L), while those with <5 hours (7.79 mg/L) and 5-6 hours (7.60 mg/L) demonstrated elevated inflammatory markers. Regarding bedtime, participants sleeping between 10-11 PM had the lowest CRP levels (4.60 mg/L), with progressive increases for later bedtimes. However, these differences were not statistically significant ($p = 0.634$ for duration, $p = 0.573$ for timing), suggesting other factors may be more influential in this young population. Our analysis reveals important insights into sleep-inflammation relationships in young adults, despite the lack of statistical significance. Participants achieving 7-8 hours of sleep with bedtimes between 10-11 PM demonstrated the most favorable inflammatory profiles, while chronic sleep insufficiency affected nearly half the population.

4. Physical Activity and Stress Management activity: Effects on CRP Concentration



Participants engaging in physical activity 2 times per week showed the highest mean CRP levels (8.31 mg/L), while those exercising daily had lower CRP levels (6.43 mg/L). Regarding stress management, participants using yoga/meditation showed elevated CRP levels (9.72 mg/L), while those combining walking with yoga had the lowest levels (4.96 mg/L). However, these differences were not statistically significant ($p = 0.755$ for activity frequency, $p = 0.489$ for stress management), suggesting individual variations may be more important than group patterns in this young population. The superior performance of walking/yoga combinations aligns with research suggesting that multimodal approaches combining aerobic activity with stress reduction techniques may be more effective than single-modality interventions.

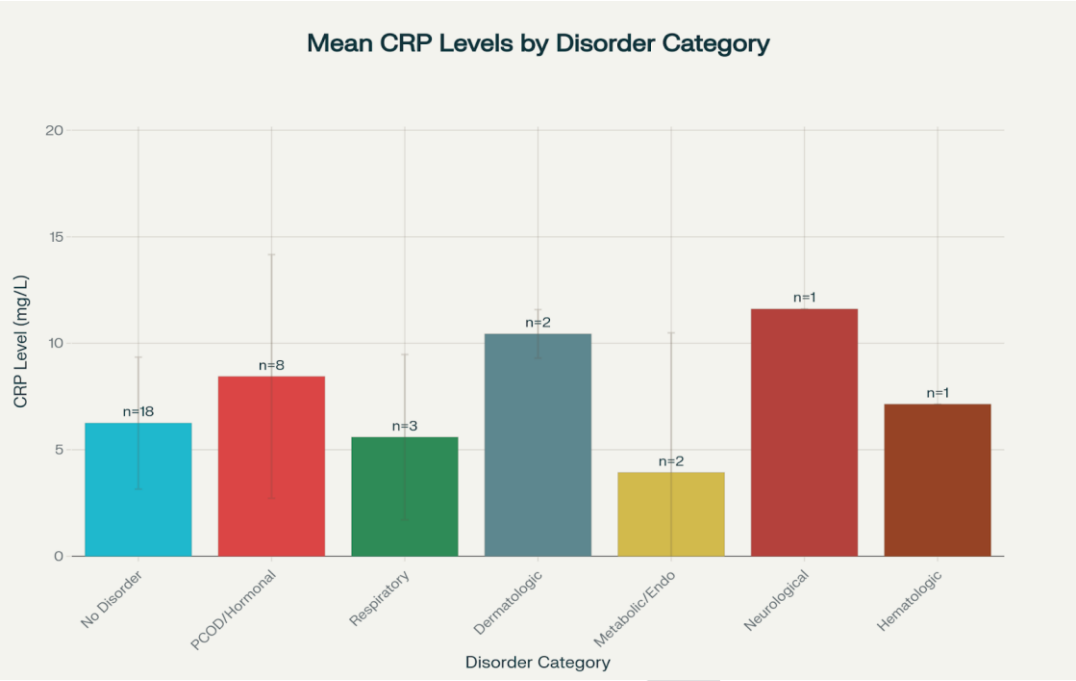
5. Smoking: Effects on CRP Concentration



Our analysis reveals surprisingly modest differences in CRP levels between substance users and non-users among young adults. Smokers showed slightly higher mean CRP levels (7.20 mg/L vs 6.93 mg/L) and alcohol consumers had marginally elevated levels (7.06 mg/L vs 6.95 mg/L) compared to non-users.

Important considerations for young adults include that alcohol's anti-inflammatory effects may be dose-dependent and require sustained moderate consumption to manifest, which may not characterize typical college-age drinking patterns.

6. Chronic and Non-Chronic Disorders: Effects on CRP Concentration



Our analysis reveals substantial inflammatory consequences of chronic disorders in young adults, with participants showing 52% higher mean CRP levels and dramatically increased cardiovascular risk profiles. The predominance of PCOD/hormonal disorders (22.9% of population) highlights the critical importance of reproductive health in systemic inflammation among young women.

Comprehensive CRP Analysis

Our comprehensive analysis of 35 young adults (aged 18-23) from our study reveals a significant inflammatory burden in this population, with 79.8% showing high or very high cardiovascular risk based on CRP levels. Chronic disorders emerged as the most impactful factor, causing a 52.4% increase in CRP levels, while family history contributed a 26.5% increase. Despite statistical limitations due to sample size, the analysis demonstrates clinically meaningful inflammatory patterns that warrant immediate attention in young adult healthcare.

1. Chronic Disorders - HIGHEST IMPACT

- Effect Size: +3.22 mg/L (52.4% increase)
- Prevalence: 25.7% of population
- Statistical: p = 0.091 (approaching significance)
- Clinical Impact: 44.4% very high-risk vs 15.4% in healthy individuals

Key Insight: Young adults with chronic disorders show immediate and substantial inflammatory consequences, with PCOD/hormonal disorders being the most prevalent (22.9% of population).

2. Gender - MODERATE IMPACT

- Effect Size: +0.59 mg/L (9.0% difference)
- Distribution: 65.7% female, 34.3% male
- Clinical Impact: Females show 4.2x higher chronic disease rates

Key Insight: Female predominance in inflammatory conditions, particularly PCOD-related disorders, creates significant gender-based health disparities.

3. Physical Activity - Highest Lifestyle Impact

Effect Size: +3.10 mg/L (+50.9% increase when inactive)

- Active participants (n=25): 6.09 ± 3.92 mg/L
- Inactive participants (n=10): 9.19 ± 3.73 mg/L
- Prevalence: 28.6% of population inactive
- Clinical Impact: MODERATE-HIGH - comparable to family history effects

4. Sleep Duration - Moderate Impact

- Effect Size: +1.87 mg/L (+32.4% increase with insufficient sleep)
- Adequate sleep (7-8h, n=15): 5.77 ± 4.06 mg/L
- Insufficient sleep (<7h, n=16): 7.65 ± 4.32 mg/L
- Prevalence: 45.7% get insufficient sleep - HIGHEST PREVALENCE
- Clinical Impact: MODERATE - widespread sleep deficiency

5. Meal Type - Variable Impact

- Effect Size: -4.14 mg/L (-50.7% decrease with high protein)
- High Protein (n=4): 4.03 ± 2.82 mg/L - PROTECTIVE
- Balanced Diet (n=12): 8.18 ± 4.00 mg/L [Reference]
- High Carb (n=15): 7.49 ± 4.28 mg/L
- Prevalence: 11.4% follow high protein diet
- Clinical Impact: HIGH - but limited prevalence

Conclusion

Chronic inflammation is a long-lasting immune response that can be protective at first but harmful if it doesn't resolve. Unlike acute inflammation, which goes away with healing, chronic inflammation quietly encourages the development of many diseases, including heart disease, type 2 diabetes, autoimmune conditions, and ongoing respiratory or gastrointestinal issues. Identifying biomarkers such as CRP, IL-6, TNF-α, ESR, SAA, and ICAM-1 helps us understand how diseases work. These markers help with diagnosis, tracking disease progression, and guiding treatment plans.

Research shows that chronic inflammation is influenced by genetics and biological factors, but it is also heavily affected by lifestyle choices like sleep, diet, and exercise. Poor sleep, unhealthy eating, and a lack of physical activity all raise systemic inflammation. On the other hand, improving these habits can lower inflammatory markers and decrease disease risk.

Overall, managing chronic inflammation needs a combined approach that includes tracking biomarkers and making lifestyle changes. Early detection, preventive health measures, and lifestyle adjustments are crucial to reducing the impact of inflammation-related diseases. They can also improve quality of life and promote a healthier lifespan. Furthermore, ongoing research into new biomarkers, better diagnostic tools, and focused therapies could lead to quicker detection and more personalized treatment options.By connecting scientific knowledge with preventive health practices, we can reduce the effects of chronic inflammatory diseases. This shift can guide us toward a more sustainable and proactive health care model.

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