



# The Relationship of Certain Diseases and Dietary Inflammatory Index in Older Adults: A Narrative Review

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## Abstract

**Purpose of Review** One of the important markers affecting aging processes is the increase in inflammatory markers. Many chronic diseases are associated with inflammation and chronic inflammation increases with aging. Inflammation can change with dietary components. Foods, compounds and nutrients that have anti-inflammatory or proinflammatory properties attract attention. According to the Dietary Inflammatory Index, positive scores are obtained if the nutrient has a proinflammatory effect on cytokines, and negative scores are obtained if it has an anti-inflammatory effect.

**Recent Findings** A higher proinflammatory diet is associated with cardiometabolic diseases, neurodegenerative disease, cancers and musculoskeletal health and related mortality. In this study, its relationship with type 2 diabetes mellitus, obesity, metabolic syndrome, musculoskeletal diseases, dementia, depression and cancer, which are more common in older adults and known to be associated with inflammation, was examined.

**Summary** Although studies involving under 65 years old are more prevalent, research involving older adults and Dietary Inflammatory Index (DII) is more limited. It is known that chronic inflammation increases with aging. Diet is one of the factors affecting inflammation. In the light of these investigations, the topics of anti-inflammatory nutrition and DII for the treatment of inflammation-related diseases in older adults are strong and open to development topics of discussion. Despite the significant interest in the potential positive effects of anti-inflammatory nutrition on diseases, contributing to clearer evidence of its protective effects on health necessitates further randomized controlled trials, in vivo, in vitro, cell, animal, human and case-control studies for better risk assessment.

**Keywords** Dietary Inflammatory Index · Inflammation · Anti-inflammatory · Proinflammatory · Chronic disease

## Introduction

Worldwide, life expectancy is increasing and the number of older adults who identify as 65 years of age or older continues to increase day by day. With the increase in the older adult population all over the world, aging has become a global phenomenon rather than an individual problem. The increase in chronic diseases, disability and frailty with aging is a priority of public health [1]. Acute inflammation is a beneficial physiological response to stress situations [2] and is necessary to protect against harmful environmental agents and bacterial and

viral infections [3]. It contributes to the elimination of threats and the repair of resulting tissue damage. In contrast, a persistent disturbance in tissue homeostasis causes chronic inflammation, a process linked to various human pathologies [2].

The generation of inflammatory mediators is referred to as the "inflammatory response," and it is regulated by activating negative feedback mechanisms, such as the release of cytokines that are anti-inflammatory, blocking proinflammatory signaling cascades, and stimulating regulatory cells. On the other hand, inappropriate, excessive or untimely production of inflammatory mediators damages the organism and diseases occur [4]. Excessive or chronic inflammatory reactions can typically damage the organism and are involved in the pathogenesis of various persistent diseases such as atherosclerosis, cancer, obesity, metabolic syndrome (MetS), asthma, neurodegeneration, depression, schizophrenia, bipolar disorder [2, 3, 5].

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## Methods

This study was conducted by searching the databases “Pub-Med, ScienceDirect, Web of Science and Google Scholar” using the following keywords alone or in combinations: “dietary inflammatory index,” “inflammation,” “anti-inflammatory,” “older adult,” “elderly,” “depression,” “dementia,” “Alzheimer's disease,” “cardiometabolic diseases,” “musculoskeletal diseases,” “cancer,” and “chronic disease.” The subreferences of the selected articles were also researched and examined. This analysis comprised studies published over the last decade that investigated the association between DII and chronic diseases (depression, dementia, Alzheimer's disease, cardiometabolic diseases, musculoskeletal diseases, cancer) in older adults. Thus, the search was narrowed down to between 2015 and 2024. The inclusion criteria for the trials considered factors such as literature review, trial design, research sample, intervention time, data collection, results, and limitations. Special attention was focused on recent studies. The current work has been grounded in research, meta-analyses, and reviews. Narrative synthesis was then undertaken to describe key findings as relevant to the aims of this review.

## The Relationship Between Inflammation and Age

Chronic inflammation represents an important phenomenon in aging [1]. An key indicator of the aging process is inflammation, which is defined as a high blood level of inflammatory markers [6]. The decline in immunity parallels the observed increase in systemic levels of proinflammatory molecules in older adults [2]. Elevations in plasma or serum levels of inflammatory mediators, including acute phase proteins and cytokines, are associated with aging [7]. Although high levels of proinflammatory cytokines shape the proinflammatory state associated with aging, the source of chronic low-grade inflammation associated with aging is not yet fully understood [8].

A common feature of aging is cellular senescence, which contributes to the morbidity and comorbidity of numerous age-related illnesses [9]. Cellular senescence is characterised by two important features: the permanent stop of cell growth and the generation of a proinflammatory secretome known as the senescence-associated secretory phenotype (SASP) [3]. Interleukin-6 (IL-6) and other proinflammatory cytokines, as well as a complex mixture of growth factors, proteases, chemokines, and matrix metalloproteinases, make up SASP. SASP-secreting cells respond by opening a self-sustaining

intracellular proinflammatory signalling cycle centred around the Nuclear Factor Kappa  $\beta$  (NF- $\kappa$  $\beta$ ), transforming growth factor-beta (TGF- $\beta$ ), interleukin-1 $\alpha$  (IL-1 $\alpha$ ), IL-6 pathway [3]. DNA damage also sets off SASP and cellular senescence [10]. Inflammation naturally increases with age. Proinflammatory molecules such as IL-6, IL-1 $\beta$  and TNF- $\alpha$  have higher systemic titers in older adults than in younger adults [2]. This causes an increase in the risk of many diseases that limit a person's healthy life span, including dementia, type 2 diabetes (T2DM), insulin resistance, cardiovascular diseases (CVD) and types of cancer [11]. Chronic inflammation with aging is a complex phenomenon. Thus, in older individuals, variations in the expression of proinflammatory genes have been linked to genetic polymorphisms [2]. Senescent cells often avoid apoptosis because they are damaged, non-dividing, and have changed metabolism [9]. Age-related diseases and disabilities are supported by a biological backdrop that is characterized by the persistence of inflammatory stimuli across time [6].

Dietary factors are a key modifiable target for reducing chronic disease risk. Through a variety of pathways, including energy balance, oxidative stress, and intestinal microbiota modification, diet influences the risk of chronic disease. These methods of action are based on the possible proinflammatory or anti-inflammatory characteristics of food patterns and individual food items [5]. Particularly for older people, the dietary plan is crucial for preserving health and lowering rates of morbidity and mortality [12].

## Dietary Inflammatory Index

The Dietary Inflammatory Index (DII) is a new tool developed to further investigate the mechanical inflammatory contribution of various dietary components [5] and specifically aims to measure the inflammatory potential of the diet. A diet that is proinflammatory has a higher DII score, whereas an anti-inflammatory diet has a lower DII score. Different cultures and eating patterns employ the same DII scores, which are standardized based on worldwide dietary intakes [13]. DII has been widely used to investigate the relationship between disease and dietary inflammatory potential. This is due to the fact that it is based on dietary nutrient intake as opposed to type of food consumed [14]. There is a direct relationship between certain dietary components and inflammation. Focusing on the overall diet quality rather than analysing individual foods is more appropriate to explain the inflammatory mechanism [15]. The DII consists of 45 nutrient parameters, including nutrients with anti-inflammatory or proinflammatory properties and compounds such as flavanoids. As opposed to specific dietary components, the nutrient matrix, or the intricate interactions

between nutrients and compounds inside foods and dietary patterns, DII refers to the study of dietary patterns [5]. Red and processed meat, high-fat dairy, and refined grains are pro-inflammatory and associated with increased levels of C-reactive protein (CRP), IL-6, and fibrinogen. However, whole grains, and green vegetables, and fruit are associated with low levels of inflammatory markers [13].

A diet higher in anti-inflammatory foods may help lower the risk of disease [16]. Dietary factors can alter the expression of inflammatory genes and the concentration of inflammatory markers in the human body. Both effects are associated with chronic diseases [14]. Anti-inflammatory diets and diets with low inflammation potential are associated with lower risks of non-modifiable diseases such as obesity, T2DM, and CVD [13]. Mechanisms potentially underlying inflammation include genomic instability, cell senescence, primary dysregulation of immune cells, mitochondria dysfunction, microbiota composition changes, and chronic infections [1]. There are several putative paths that could explain the correlation with dietary inflammatory potential and early mortality, even though the exact mechanisms are unknown. Elevated inflammatory potential may increase the amount of inflammatory components such as IL-4, IL-6, IL-10, IL-1 $\beta$  and accelerate the rate of telomere shortening. Proinflammatory diets tend to include ingestion of saturated fats, which are notably linked to a higher risk of cancer and CVD mortality. They may also raise the concentrations of Very Low-Density Lipoprotein (VLDL), Low-Density Lipoprotein (LDL), and Tumor Necrosis Factor-alpha (TNF- $\alpha$ ), all of which are linked to a higher risk of mortality [14].

## Diseases Associated with DII in Older Adults

Studies on the effects of both acute and chronic inflammation on illness and health emphasize how crucial nutritional status is. Specific foods are known to have strong effects on inflammatory pathways in the body. For this reason, avoiding proinflammatory foods when choosing foods is at the centre of an anti-inflammatory nutrition plan [17].

## Neurodegenerative Diseases

### Depression

According to the World Health Organization, depression accounts for 4.3% of all diseases globally, making it one of the leading causes of disability worldwide [18]. Depressive symptoms are also common and persistent in older adults. This condition is associated with decreases in physical performance and mortality [19]. The incidence of geriatric depression is higher in those with medical illnesses and

those in long-term care [7]. The pathophysiology of depression involves inflammation [18]. Proinflammatory diets may increase risk of depressive symptoms [20]. Cytokines produced in the brain by microglia and other central nervous system cells are important positive modulators of various central nervous system functions, such as maintaining neuroplasticity. Nevertheless, protracted or excessive inflammatory cytokine activity impairs many neuronal functions, such as neurotransmitter signaling and the production, reuptake and release of neurotransmitters. This affects functions related to mood and cognitive processes [21, 22].

In one study, an elevated likelihood of depressive symptoms was linked to higher DII scores, which indicate a diet that is more proinflammatory [23]. An association between dietary inflammation and depression symptoms was discovered in a different investigation. Proinflammatory food consumption has been linked to an increased risk of depression and depressive symptoms [24]. Sánchez-Villegas et al. [25] reported in their study that elevated DII values were linked to depression, and that there was a stronger relationship among participants over 55 years of age and those with cardiometabolic comorbidities. In a cohort study of older persons, based on the DII score, a proinflammatory diet was linked to a higher incidence of depressed symptoms [26]. Bruno Bizzozero-Peroni et al. [27] found a link between the incidence of depression in older persons and a diet high in inflammation. Ruiqiang Li et al. [20] found in their study that the prevalence of depression in individuals over the age of 55 was 23.4%. Older patients with depression have a higher potential for dietary inflammation. Another study reported a strong association between diversified dietary intake, especially anti-inflammatory diets, and depressive symptoms in older adults [28]. It is stated that understanding the biomarkers of stress and inflammation during the aging process, therapeutic and preventive strategies for mood and cognitive issues in later life may be developed [29].

Some studies examining the relationship between DII and depression are summarized in Table 1.

## Dementia and Alzheimer's Disease

The immune system's erratic behavior combined with inflammatory food habits may make cognitive decline more likely. But the exact processes by which inflammatory eating patterns may affect the onset of cognitive decline in older adults remain unclear [30]. Systemic inflammation is an important driver of cognitive decline in older adults [31]. It has been reported that a diet with proinflammatory properties is associated with poorer cognitive functions later in life and a higher risk of cognitive impairment or dementia [32]. Semantic, working, and episodic memory deficiencies were linked to higher DII scores [33]. It is

**Table 1** Some studies examining the relationship between DII and depression

References	Study Types	Participants	Method	Findings and Results
[18]	Cohort	3523 participants (35–60 years old)	Center for Epidemiological Research Depression Scale, 24-h food consumption record, DII	Men with higher DII scores have a higher risk of depressive symptoms
[20]	Cohort	2022 participants (aged 55 and over)	Food Frequency Questionnaire, DII	The risk of depression was significantly higher in participants in the proinflammatory group than in participants in the anti-inflammatory group
[27]	Cohort	3206 older adults	Geriatric Depression Scale, Food consumption record survey, DII	Proinflammatory diet is associated with risk of depression in older adults
[28]	Cross-sectional study	12,192 participants (aged 65 and over, average age 83.6 years)	Epidemiological studies depression scale, Dietary diversity index, DII	A diversified diet, especially intake of anti-inflammatory nutrients, is associated with a lower risk of depressive symptoms
[23]	Cross-sectional study	2047 adult	Questionnaire (dietary frequency, CES-D, HADS-A and WHO-5 screening tools), DII	Higher DII scores are associated with an increased risk of depressive symptoms
[25]	Cohort	15,093 adults	DII, Food consumption record survey	High DII scores are associated with depression. This relationship is stronger in participants over 55 years of age and with cardiometabolic comorbidities
[24]	Cross-sectional study	11,624 adults aged 18 and over	Framingham Risk Score, DII	Dietary inflammation is associated with depression symptomology
[26]	Cohort	3648 participants (1577 men, 2071 women; average age: 60.6 years)	Block Brief 2000 Food Frequency Questionnaire, DII, Depression-20 scale	Participants on the most proinflammatory diet had an approximately 24% higher risk of developing depressive symptoms than those on the most anti-inflammatory diet. Proinflammatory diet is associated with a higher incidence of depressive symptoms in older adults

noted that many of the proteins found in an inflammatory diet are also affiliated with the risk of dementia, and are connected with plasma biomarkers of neurodegeneration and the pathophysiology of Alzheimer's disease (AD) [30]. Higher DII scores may be associated with increased risk of dementia, indicating that individual-specific and targeted dietary interventions could benefit the development of strategies aimed at primary prevention of dementia [34]. Patients with AD are susceptible to many complications including increased inflammatory markers and oxidative damage, mortality, microvascular disease, dyslipidaemia and insulin resistance [35]. In a large cohort study, it was observed that the risk of all-cause dementia increased with increasing DII levels [36]. In another prospective cohort study, an association was found between high DII scores and the incidence of all-cause dementia and AD. It has been observed that individuals with a proinflammatory dietary habit and a high AD genetic risk score have a higher risk of AD [37]. Inflammatory dietary burden was associated with links to cognitive decline in older individuals over 60 years of age [38]. The Mediterranean diet, a dietary pattern rich in anti-inflammatories, has been associated with better cognition and lower incidence of dementia [39]. A dietary pattern rich in fruits, leafy green vegetables, fish, nuts, and olive oil is associated with a slowdown in cognitive decline and a reduced risk of dementia [40].

The depletion of estrogen post-menopause predisposes women to cognitive decline due to increased risk of chronic inflammation. In a study conducted on postmenopausal women, individuals adhering to a proinflammatory diet were found to have a higher likelihood of cognitive impairment compared to those adhering to an anti-inflammatory diet [41]. It has been reported that individuals with vascular dementia tend to consume deep-fried foods and full-fat dairy products more frequently and engage in less physical exercise. These patients also exhibit a higher prevalence of dyslipidemia, with increased intake of saturated fats, trans fats, and cholesterol being implicated in elevating the risk of dementia. However, higher consumption of fish and DHA has been associated with a lower risk of vascular dementia and cognitive decline [42].

Some studies examining the relationship between DII and Dementia and Alzheimer's disease are summarized in Table 2.

In conclusion, proinflammatory diets may be linked to an increased risk of dementia and depression, while inflammatory diets may raise the risk of age-related cognitive decline and dementia. More *in vivo*, *in vitro*, animal and human clinical and epidemiological studies are needed to examine the effect of anti-inflammatory nutrition on cognition to gain a deeper comprehension the relationship between neurodegenerative diseases and DII, to emphasize its relationship with nutrition and to make generalizations.

## Cardiometabolic Diseases

Populations at high risk of cardiometabolic disease constitute a significant proportion of the world [43]. Cardiometabolic disorders are a group of interrelated conditions and risk factors that include a range of health problems such as diabetes, obesity, stroke, CVD, hypertension, dyslipidemia, MetS [44]. Especially the older adult population is at the center of attention in terms of cardiometabolic diseases [44]. A high inflammatory diet is linked with MetS, hypertension, hyperglycaemia, abdominal obesity and hypertriglyceridemia. An increase in the DII is associated with a higher incidence of abdominal obesity and hyperglycemia in overweight individuals. Increased body mass index (BMI), weight growth, and the likelihood of becoming obese have all been linked to higher DII scores [45], which are related to chronic low-grade inflammation both locally in the systemically and gut [46]. Proinflammatory diet has been directly associated with high levels of proinflammatory markers such as IL-1 $\beta$ , IL-6, TNF- $\alpha$  and CRP [47]. In a study conducted on men, a significant increase in the DII scores with increasing age has been demonstrated. DII has been shown to have positive correlations with age and obesity indices, suggesting that diet may play a role in the emergence of obesity in older adults through inflammatory modulation mechanisms [48]. It has been discovered that people who follow a diet pattern with a higher DII score accumulate more fat overall, in their visceral adipose tissue, and in their liver [49]. In a cohort study examining individuals aged 20–90 years, among those with a normal BMI range, a proinflammatory diet measured by high DII scores was linked to a higher risk of CVD mortality in individuals with central obesity [50]. In metabolically unhealthy overweight/obese people, a proinflammatory diet was found to raise the risk of cardiovascular and all-cause mortality in a study utilizing NHANES data [15]. Another study found that a proinflammatory diet increased the risk of all-cause mortality in adults with abdominal obesity or overweight/obesity [51]. It is assumed that the relationship between obesity and inflammation is bidirectional. In a study involving an eight-year follow-up, the risk of developing overweight or obesity was found to be lower in individuals with anti-inflammatory diets than in individuals with proinflammatory diets [52]. Rather from being the cause of T2DM and obesity, chronic inflammation is a result of both [53]. Additionally, there is a positive correlation between DII and the prevalence of central obesity in postmenopausal women and hyperglycemia in males [54]. The pathogenesis of T2DM and CVD is linked to chronic systemic inflammation, which is characterized by inflammatory cytokine levels that are consistently elevated in the blood. In a study involving adults, the risk of MetS increased 1.28-fold in individuals following a proinflammatory diet [55].

Higher amounts of cytokine release in the blood stream of fat tissue in obese individuals with MetS and higher CRP



**Table 2** Some studies examining the relationship between DII and Dementia and Alzheimer's

References	Study Types	Participants	Method	Findings and Results
[32]	Cohort	7085 women (65–79 years old)	Food Frequency Questionnaire, DII, Annual cognitive function assessment	There were an average of 1081 cases of cognitive impairment over 9.7 years. Higher DII scores are associated with greater cognitive decline and earlier onset of cognitive impairment
[30]	Cohort	1528 women with onset age 71.3 years	Food Frequency Questionnaire, DII, blood analyses, energy-adjusted oliv protein measurement, standard neuropsychological tests	A number of inflammatory dietary proteins were identified whose levels were associated with risk of cognitive impairment over a fourteen-year follow-up period, and several of the same proteins were shown to be associated with risk of dementia in two outgroups and were correlated with plasma
[34]	Cohort	1059 participants (average age 73.1 years)	Food Frequency Questionnaire, DII	Higher DII scores are associated with increased risk of dementia
[41]	Cross-sectional study	222 postmenopausal women (average age 61 years)	Mini-Mental State Examination, DII, biochemical inflammatory markers measured by ELISA test	A proinflammatory diet is positively associated with an increased risk of cognitive impairment in postmenopausal women
[42]	RCT	150 individuals with vascular dementia	A cross-sectional survey examining diet and lifestyle patterns, DII	There is an inverse relationship between healthy lifestyle factors and vascular dementia in both men and women
[36]	Cohort	166,377 participants	Brain MRI image, food consumption record with 24-h recall method, DII	The risk of dementia increases with a high DII score. There is a “J-shaped” non-linear relationship between AD and DII
[37]	Cohort	207,301 individuals aged 39–72	Alzheimer's disease genetic risk score, food consumption record with 24-h recall method, DII	There is a significant association between high DII scores and the incidence of dementia and AD. The risk of AD is higher in high AD-genetic risk score participants with proinflammatory dietary habits
[33]	Cross-sectional study	1723 adult individuals aged 60–85	Consortium to Establish a Registry for Alzheimer's disease (CERAD) Word Learning subset, the Animal Fluency test and the Digit Symbol Substitution Test (DSST), Food consumption record with 24-h recall method, DII	Higher DII scores are associated with worse episodic memory, working memory and semantic memory

production in the liver explain the relationship between MetS and CRP [56]. According to another cohort study, higher DII scores were associated with an increased risk of MetS. Significantly higher intake of flavan-3ols, flavonols, tea, isoflavones, polyunsaturated fatty acids, onions, fiber, folate, protein, as well as vitamins A, C, E, B1, B2 and B6, which are associated with a more inflammatory diet lower MetS has been associated with the risk [56]. Components of MetS are associated with subclinical inflammation and DII [57]. In a meta-analysis, although proinflammatory and anti-inflammatory diets were not associated with the risk of MetS, DII was found to be associated with the risk of CVD and all types of mortality [58]. Individuals adhering to a proinflammatory diet have a 38% higher risk of developing CVD [59].

In a prospective cohort study conducted in France, it was discovered that people with high DII scores had an increased risk of developing MetS following a 12.4-year follow-up period [60]. Numerous research have looked into the connection between DII and MetS, but findings are inconsistent [54, 57, 58, 60]. In a longitudinal study, six months following bariatric surgery, a proinflammatory diet at first was linked to lower decreases in body weight and body fat as well as inferior nutritional quality (reduced consumption of vegetables, fruits and legumes) [45]. Another meta-analysis shows that a high DII scores are linked to higher BMI and obesity [61]. In the NHANES study, participants with chronic heart disease (CHD) were found to have significantly higher DII scores compared to those without CHD. Additionally, it was observed that women are more sensitive to DII [62].

Some studies examining the relationship between DII and cardiometabolic disease are summarized in Table 3.

Unhealthy dietary habits lead to chronic systemic inflammation, which is a key characteristic of metabolic diseases. Evidence suggests that reducing dietary inflammation may potentially decrease the risk of cardiometabolic diseases and associated mortality. However, evidence regarding the relationship between DII and conditions such as obesity, diabetes and MetS is conflicting and inconsistent. Owing to the small sample sizes in many studies, more case–control and prospective studies are needed to understand the association between DII and cardiometabolic diseases and to make generalizations about its association with nutritional status.

## Musculoskeletal Health

The most common bone diseases among adults and older adults are osteoporosis and osteomalasia [67]. It's feasible that dietary inflammation and nutrients directly affect the mineralization of bone [16]. The impact of an inflammatory diet on fractures is little understood, despite the fact that nutrition can be a source of inflammation [68]. Research indicates that increased levels of inflammation are linked

to bone loss and fracture risk, and that these levels may be lowered with dietary interventions [68, 69]. High DII score is also associated with decreased bone mineral density [70]. In a study, it was observed that women with high DII scores had a significantly higher risk of bone fractures [68]. Individuals with high intake of proinflammatory nutrients and low intake of anti-inflammatory nutrients have a higher risk of sarcopenia [71]. In a meta-analysis, it was reported that high DI increased the risk of sarcopenia [72]. In older adult men, a more proinflammatory diet is connected to the lumbar spine and lower hip bone mineral density, as well as a higher incidence of fractures and falls. Conversely, in women, a more proinflammatory diet is associated with higher lower extremity muscle quality and a lower risk of fractures [12]. Fang et al. [73] reported that higher DII scores were associated with lower bone mineral density in the lumbar spine and total hip, as well as increased risk of osteoporosis and fractures. Conversely, the Mediterranean diet, which is anti-inflammatory in nature, has been shown to have positive effects on hip fracture risk and lumbar spine bone mineral density in older adults [74].

A negative correlation between DII and bone mineral density was obtained when  $DII > 0.35$  in patients with chronic kidney disease. The bone mineral density of the femur and femoral neck decreases with increasing DII score [75]. Postmenopausal women are in a high risk group for the development of osteoporosis because they experience rapid bone loss with hormonal changes [67]. Postmenopausal women with higher DII scores have been found to be associated with a more proinflammatory dietary pattern, which in turn is correlated with low bone mineral density [15]. In a study, it was observed that an increasing DII score, indicating a proinflammatory diet, is a risk factor for low bone mineral density in the lumbar spine [76]. Women with lower DII scores, which suggest a less inflammatory dietary pattern, were linked to decreased bone mineral density loss in another study involving postmenopausal women [69]. In another study conducted with postmenopausal women revealed that an increase in DII score is a risk factor for osteoporosis [77].

A significant association has been found between adherence to the Mediterranean diet and a lower risk of hip fracture [78]. In another study, higher DII scores were found to be associated with lower bone density, increased risk of falls, and higher incidence of fractures in older adult men [12]. In a case–control study in older adults, a proinflammatory diet was positively associated with hip fracture risk [79]. Veronese et al. [80] found that participants with a more proinflammatory diet and higher DII score had a significantly higher prevalence of radiographically symptomatic knee osteoarthritis. In another study, a more proinflammatory diet was associated with a higher incidence of fractures in women, while the findings were not significant

**Table 3** Some studies examining the relationship between DII and cardiometabolic disease

References	Study Types	Participants	Method	Findings and Results
[55]	Cross-sectional study	Adult 2022 individuals aged 55 and over	Food consumption record, DII,	The risk of depression was significantly higher in participants in the proinflammatory group than in participants in the anti-inflammatory group. DII is significantly associated with depression risk in overweight and obese individuals
[48]	Cross-sectional study	651 elderly male participants (54–95 years old)	Food consumption record with 24-h recall method, DII, Dietary Phytochemical Index, net rate of endogenous noncarbonic acid production (NEAP)	As age increased, the DII score increased significantly DII shows positive correlations between age and obesity indices. Diet plays a role in the development of obesity in the elderly through inflammatory modulation mechanisms
[57]	Cross-sectional study	7689 participants (average age 45.8)	Food consumption record, DII, Blood analysis	Proinflammatory diet as measured by DII is associated with worsening cardio-metabolic risk profile
[54]	Cross-sectional study	9291 adults (19–65 years old, average age 41.3 years)	Food consumption record with 24-h recall method, DII, Blood analysis	DII is significantly associated with the prevalence of MetS in men and postmenopausal women. DII is also positively associated with the prevalence of hyperglycemia in men and central obesity in postmenopausal women
[60]	Cohort	3726 participants (Average age at baseline $48.9 \pm 6.2$ years and mean follow-up $12.4 \pm 1.0$ years)	Food consumption record with 24-h recall method, DII, Blood analysis	Higher DII scores are positively associated with a higher risk of MetS. The strongest associations are with blood pressure, triglycerides, and HDL cholesterol
[45]	Longitudinal study	132 women with obesity (BMI $\geq 35$ kg/m <sup>2</sup> , $43.0 \pm 9.7$ years)	Food consumption record with 24-h recall method, DII, Blood analysis	An initial proinflammatory diet is associated with smaller reductions in body weight and body fat and poorer diet quality (reduced consumption of fruits, vegetables, and legumes) 6 months after bariatric surgery
[49]	Cohort	812 men, 843 women, ages 60–77	Food Frequency Questionnaire, DII, Stool and blood analysis, DXA-derived total fat mass, MRI-measured VAT, and MRI-based liver fat	There is a positive relationship between DII and total fat mass and fatty liver. There is no significant relationship between the DII score and the steatosis phenotype via hs-CRP
[56]	Cohort	157,812 participants, ages 40–79 men = 53,304; women = 104,508	Semi-Quantitative Food-Frequency Questionnaire, DII	In postmenopausal women, higher DII scores are positively associated with MetS
[50]	Cohort	3521 adults aged 20–90	Food consumption record with 24-h recall method, DII	A high DII score is associated with an increased risk of CVD mortality. This relationship is stronger in more severe central obesity
[52]	Cohort	727 participants (BMI < 25 kg/m <sup>2</sup> )	Food-Frequency Questionnaire, DII	After an average follow-up of 8.1 years, 1433 cases of overweight/obesity were observed. A proinflammatory diet is associated with greater weight gain and the development of obesity
[59]	Cohort	74,578 women from the Nurses' Health Study, 91,656 women from NHSII, 43,911 men from the Health Professionals Follow-up Study	Food-Frequency Questionnaire, DII, food-based empirical dietary inflammatory pattern score	Individuals with a more proinflammatory diet have a 38% higher risk of developing CVD after adjusting for risk factors and confounders



Table 3 (continued)

References	Study Types	Participants	Method	Findings and Results
[62]	Cross-sectional study	45,306 adults from NHANES (ages 18–80)	Food consumption record with 24-h recall method, DII, Healthy Nutrition Index	DII <sub>s</sub> in participants with CHD were significantly higher compared to those without CHD. Women are more susceptible to DII than men
[63]	Prospective cohort	41,513 adults (ages 40–69 years)	Food-Frequency Questionnaire, DII, Blood analysis, physical measures, Mediterranean Diet Score	Diets that are less inflammatory or more Mediterranean are linked to lower mortality. DII score was not more strongly associated with mortality than was the Mediterranean Diet Score
[64]	Randomized controlled trial	137 healthy men and women (aged 65 years and above)	Blood pressure measurement, anthropometric measurement, Food-Frequency Questionnaire, 3-day weighed food record, DII	High adherence to a Mediterranean Diet intervention over 6 months in Australian older adults has been shown to significantly reduce mean DII compared to the habitual diet
[65]	Cross-sectional study	100 adult patients (40–60 years old)	Food-Frequency Questionnaire, DII, Mediterranean Diet Score, blood pressure measurement, anthropometric measurement, biochemical parameters	Participants with higher adherence to the Mediterranean diet had significantly lower DII scores and higher levels of antioxidant enzymatic activity in their plasma
[66]	Randomized controlled trial	56 participants (84% male, mean age 62 ± 9 years)	DII, 7-day food diaries, self-report survey, anthropometric measurement, biochemical parameters	Participants were randomized 1:1 to either the low-fat diet group or the Mediterranean diet group. When compared to the low-fat diet, the results showed that the Mediterranean diet intervention dramatically lowered DII scores. Nevertheless, there was no discernible change in the assessed inflammatory markers in this small group of coronary heart disease patients

**Table 4** Some studies examining the relationship between DII and musculoskeletal health

References	Study Types	Participants	Method	Findings and Results
[71]	Cross-sectional study	201 older adults (60–85 years old)	Food-Frequency Questionnaire, DII, anthropometric measurements, hand grip strength measurement	A more proinflammatory diet with higher DII scores is associated with an increased risk of sarcopenia in older adults
[12]	Cohort	1098 elderly individuals (average age 63.0)	Food-Frequency Questionnaire, DII, dual energy x-ray absorptiometry, Physical Profile Assessment (PPA)	High DII scores are associated with lower bone density, higher risk of falls, and increased incidence of fractures in older men. High DII scores are associated with reduced fracture incidence in women over 10 years
[67]	Cross-sectional study	272 post-menopausal women (average age 55)	Food-Frequency Questionnaire, DII, DXA scan	No significant relationship was found between dietary inflammation and bone health
[15]	Cross-sectional study	2778 post-menopausal women	Food consumption record with 24-h recall method, DII, DXA scan	High DII scores are associated with lower bone mineral density in postmenopausal women
[76]	Cross-sectional study	160 post-menopausal women (ages 50–85)	Food-Frequency Questionnaire, DII, dual energy x-ray absorptiometry	High DII scores are associated with below-average bone mineral density at the lumbar spine in postmenopausal women
[69]	Longitudinal study	160,191 participants, (ages 50–79, average age 63)	Food-Frequency Questionnaire, DII, fracture reports	Postmenopausal women with less inflammatory DII scores had lower hip bone mineral density at baseline. But they lost less bone mineral density at the hip over 6 years than women who consumed a more inflammatory diet
[79]	Cross-sectional study	1050 participants, ages 52–83	Food-Frequency Questionnaire, DII, fracture reports	Proinflammatory diet associated with high DI score is positively associated with hip fracture risk
[80]	Cross-sectional study	4358 participants (average age 61.2)	Food-Frequency Questionnaire, DII	Participants with high DII scores had a significantly higher prevalence of radiographic symptomatic knee osteoarthritis compared with participants with low DII scores
[68]	Longitudinal study	3648 participants at risk of knee osteoarthritis (1577 men and 2071 women; average age 60.6)	Block Brief 2000 Food Frequency Questionnaire, DII, Story about fractures	A proinflammatory diet is associated with a higher incidence of fractures in women but not men
[81]	Cross-sectional study	2269 participants (aged 40 and over)	Food consumption record with 24-h recall method, DII	Men's DII score is lower than women. There was no significant relationship between DII scores and low-impact fractures
[82]	Cross-sectional study	1023 women and 1080 men participants (age $\geq$ 50)	DII, The BMD of lumbar spine, femoral neck, and total hip were measured by dual-energy X-ray absorptiometry (DXA)	Higher DII scores are associated with an increased risk of osteoporosis in women, but no association was found in men
[75]	Cross-sectional study	2276 participants from 2009–2018 NHANES	Food consumption record with 24-h recall method, DII	A negative correlation was obtained between DII and bone mineral density when DII was $> 0.35$

Table 4 (continued)

References	Study Types	Participants	Method	Findings and Results
[77]	Cross-sectional study	850 post-menopausal women (ages 50–65)	Food consumption record with 24-h recall method, DII	A proinflammatory diet is a risk factor for osteoporosis in postmenopausal Iranian women
[12]	Cross-sectional study	794 men from the Concord Health and Male Aging Project (age $81.1 \pm 4.5$ years)	Food-Frequency Questionnaire, DII, DXA for bone mineral density	Consumption of a proinflammatory diet is associated with increased concentrations of IL-6, IL-7, and TNF- $\alpha$ and an increased risk of falls
[86]	120 Rheumatoid Arthritis patients (73.3% female, $61.8 \pm 10.1$ years of age)	Food-Frequency Questionnaire, DII, Mediterranean Diet assessment tool, Disease Activity Score of 28 Joints, Rheumatoid Arthritis Impact of Disease questionnaire, Health Assessment Questionnaire	Higher adherence to the Mediterranean Diet was significantly associated with lower disease activity, lower impact of disease and lower functional disability in Rheumatoid Arthritis patients. No associations between macronutrient intake or DII and Rheumatoid Arthritis outcomes were found	120 Rheumatoid Arthritis patients (73.3% female, $61.8 \pm 10.1$ years of age)

in men [68]. There was no correlation found by the Brazilian Osteoporosis Study between DII scores and low-impact fractures [81]. In another study, no significant relationship was found between DII and bone health in postmenopausal women [67]. Zhao et al. [82] found that higher DII scores were associated with an increased risk of osteoporosis in women, while no association was found in men. A study conducted with 794 men, with an average age of 81.1 years, found that a proinflammatory diet increased the concentrations of inflammatory markers IL-6, IL-7, and TNF- $\alpha$ , as well as the risk of falls [12]. A meta-analysis revealed that poorer skeletal muscular strength, mass, and sarcopenia risk were strongly correlated with the increased dietary inflammatory potential correlated with high DII [83].

Results from individual, observational and longitudinal cohort studies have shown that a proinflammatory diet has negative effects on fracture risk [12, 68, 69], bone mineral density [15, 69, 84], osteoporosis [67] and sarcopenia [71, 72]. High DII scores have also been associated with frailty [85].

However, there are discrepancies in the literature regarding the relationship between DII and bone health. Further studies are needed to better understand the relationship between DII and musculoskeletal health.

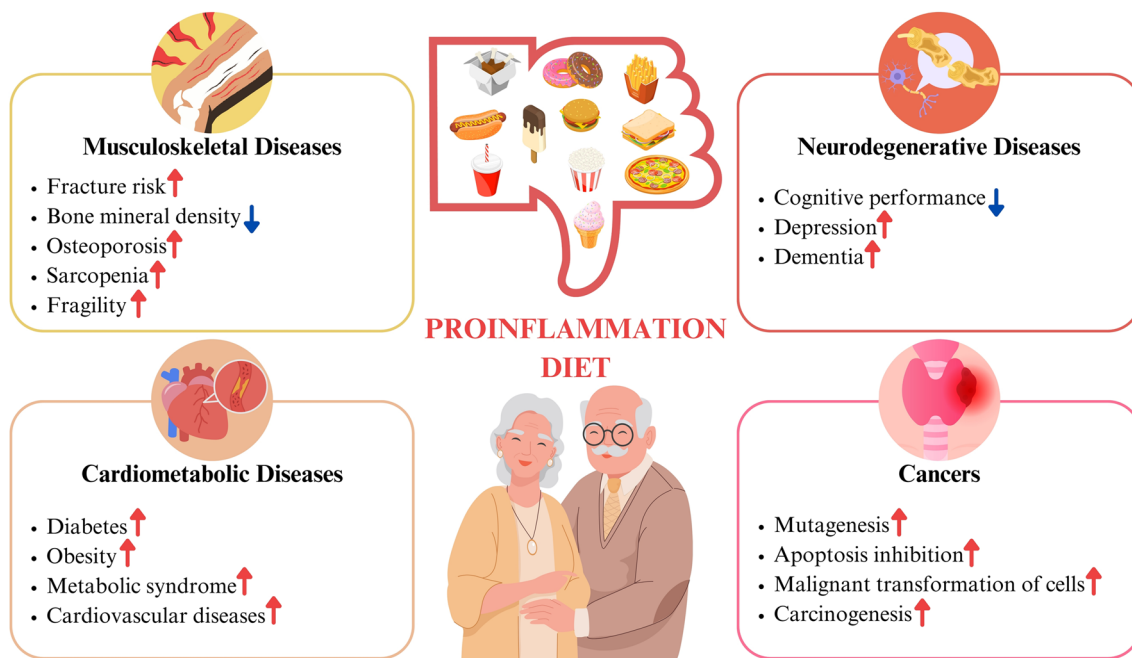
Some studies examining the relationship between DII and musculoskeletal health are summarized in Table 4.

## Cancer

Inflammation is considered a crucial factor in carcinogenesis. It is thought that a major factor in the carcinogenesis of inflammation-related disorders may be stem cell-induced oxidative and nitrosative DNA damage. DNA damage can lead to mutations and may play a role in initiating and/or supporting inflammation-mediated carcinogenesis [87]. Inflammation-induced reactive oxygen and nitrogen species harm not just DNA but also other macromolecules like proteins and lipids, leading to their malfunction. Roughly 25% of cancer-causing factors are caused by infection, and mutagenic DNA lesions are a hallmark of malignancies connected to inflammation [88]. Chronic inflammation is known to be a risk factor for cancers in various regions [87]. Diet is a significant source of bioactive compounds that have the potential to interact with chronic inflammation. This can result in the growth of cells, mutagenesis, suppression of apoptosis, and the release of mediators that may encourage the malignant transformation of cells and the development of cancer [89]. There is a linear dose–response relationship between DII and overall cancer risk [90]. Higher DII scores have been linked to a higher incidence of breast cancer [91]. It has been shown that among obese participants, a greater DII is linked to an increased risk of gynecological cancers, particularly ovarian and endometrial cancer [89].

**Table 5** Some studies examining the relationship between DII and cancer

References	Study Types	Participants	Method	Findings and Results
[95]	Case-control study	690 bladder cancer patients, 655 cancer-free control group	Food-Frequency Questionnaire, DII	People with higher DII scores are associated with an increased risk of bladder cancer
[96]	Case-control study	304 esophageal squamous cell cancer patients, 743 control group	Food-Frequency Questionnaire, DII	People with higher DII scores are associated with an increased risk of esophageal squamous cell cancer
[98]	Case-control study	460 laryngeal cancer patients, 1088 control group	Food-Frequency Questionnaire, DII	People with higher DII scores are associated with an increased risk of laryngeal cancer
[84]	Case-control study	1031 women with ovarian cancer, 2422 women in the control group	Food-Frequency Questionnaire, DII	Women with higher DII scores are associated with an increased risk of ovarian cancer
[99]	Case-control study	536 non-Hodgkin lymphoma patients, 984 control group	Food-Frequency Questionnaire, DII	A diet with a higher DII score is associated with a higher risk of non-Hodgkin lymphoma, especially in men
[101]	Case-control study	47 esophageal squamous cell cancer patients, 96 control group	Food-Frequency Questionnaire, DII	A diet with a higher DII score is associated with an increased risk of esophageal squamous cell cancer
[93]	Case-control study	Total 313 people n = 99 (colorectal cancer patients); n = 73 (colonic polyps); n = 141 (healthy controls)	Food-Frequency Questionnaire, DII	A more proinflammatory diet is associated with an increased risk of colorectal cancer
[85]	Cross-sectional study	13,563 participants	Food-Frequency Questionnaire, DII	DII increased with age and was lower in men than in women. The DII score is associated with cancer risk for the other sites considered (oral cavity, pharynx, nasopharynx, larynx, esophagus, stomach, colon, rectum, pancreas, breast, ovary, prostate, kidney, bladder), except for the liver and endometrium
[102]	35,303 participants (age 27–75 years)	Food-Frequency Questionnaire, Mediterranean Diet Score, DII	An inverse correlation was observed between the DII and Mediterranean Diet Score	35,303 participants (age 27–75 years)
[103]	Cases (n = 297), controls (n = 307) (age 40–74 years women)	Food-Frequency Questionnaire, lifestyle questionnaire, Mediterranean diet index, DII	High vegetable consumption, adherence to the Mediterranean diet, and a low DII have been shown to have a protective effect on reducing the risk of endometrial cancer	Cases (n = 297), controls (n = 307) (age 40–74 years women)
[104]	33,690 people (13,283 men and 20,407 women, age 40–69 years)	Food-Frequency Questionnaire, Mediterranean Diet Score, DII, Alternative healthy eating index-2010	Stronger adherence to the Alternative healthy eating index (healthier diet) was found to be associated with a decreased incidence of pancreatic cancer; however, the Mediterranean Diet Score and DII showed weaker evidence, though consistent in direction	33,690 people (13,283 men and 20,407 women, age 40–69 years)



**Fig. 1** Summary of findings regarding certain diseases and DII in older adults

According to the results of a meta-analysis, a more proinflammatory diet is associated with increased risk of prostate cancer, kidney cancer, and bladder cancer. However, there is no association between DII and urothelial carcinoma [92]. The consumption of diets with higher proinflammatory potential has been linked to an increased risk of colorectal cancer in obese people, according to new research [93]. It has been emphasized that as DII scores increase, the risk of prostate cancer also increases and promoting diets rich in anti-inflammatory nutritional components may help prevent prostate cancer [94]. In case–control studies conducted by Shivappa et al. proinflammatory diet, indicated by higher DII scores, was associated with an increased risk of bladder [95], esophageal squamous cell [96], mouth and pharynx [97], laryngeal [98], ovarian cancers [84] and non-Hodgkin lymphoma [99]. In another study, men exhibiting higher DII scores and premenopausal women showed increased incidence risks of prostate and breast cancer, respectively. Furthermore, a favorable correlation has been noted between women's breast cancer risk and their BMI and DII score [100]. A case–control study has shown that a proinflammatory diet is associated with an increased risk of esophageal squamous cell carcinoma [101].

Some studies examining the relationship between DII and cancer are summarized in Table 5.

Studies conducted in various populations from different countries have shown consistent relationships between DII scores and a wide range of cancer types. Further case–control, clinical, and high-quality prospective studies are needed

to better understand the relationship between DII and different types of cancer.

## Conclusion

Inflammation is an important factor for pathophysiologies associated with aging such as depression, cognitive performance and decline, carcinogenesis, and bone mineralization. Studies indicate that higher DII scores, which reflect a more proinflammatory diet, are associated with an increased risk of certain cancers, neurodegenerative diseases, cardiometabolic diseases, musculoskeletal diseases and related mortality, and the relationship of dietary inflammation in the pathophysiology of these diseases. Figure 1 summarizes the findings related to certain diseases and the DII in older adults. Figure 1 summarizes the findings related to certain diseases and the DII in older adults. Particularly in the older adult population, emphasizing the benefits of a more anti-inflammatory dietary plan is highlighted to reduce disease risks and mortality. Proinflammatory diets have been linked to an increased risk of cancers, neurodegenerative, cardiometabolic, musculoskeletal, and other diseases in older adults. To better understand the relationship between DII and neurodegenerative diseases, to emphasize its relationship with nutrition, and to make generalizations, more *in vivo*, *in vitro*, animal, human clinical, and epidemiological studies are needed to examine the effects of anti-inflammatory nutrition on diseases common in older adults.



## Suggestions and Future Perspective

Although studies involving adults are more prevalent, research involving older adults and DII is more limited. It is known that chronic inflammation increases with aging. Diet is one of the factors affecting inflammation. In the light of these investigations, the topics of anti-inflammatory nutrition and DII for the treatment of inflammation-related diseases in older adults are strong and open to development topics of discussion. Despite the significant interest in the potential positive effects of anti-inflammatory nutrition on diseases, contributing to clearer evidence of its protective effects on health necessitates further randomized controlled trials, in vivo, in vitro, cell, animal, human and case–control studies for better risk assessment. It is beneficial to explain the importance of the Mediterranean diet to individuals in order to protect and improve their health across all life stages, ensuring adequate and balanced nutrition, and providing nutrition education and guidance to ensure its sustainability. To assess the reliability and effectiveness of the excessively consumed anti-inflammatory diets (DII used to examine the effectiveness of this diet) and to clarify and strengthen current evidence due to conflicting data regarding the prevention of inflammation-related diseases, longer-term studies are beneficial.

## Limitations

This review is based on the analysis of studies found in the literature and therefore the limitations of the study are limited to the scope of the sources reviewed. Most of the studies examined are observational studies, and such studies inherently have limitations in determining causal relationships. Although the findings presented in this review provide a general framework, they are insufficient to determine the role of individual lifestyle factors and genetic variations in the relationship between inflammation and chronic diseases. The lack of studies to evaluate the effectiveness of an anti-inflammatory nutrition plan, especially in the older adult population, and the lack of more data on the feasibility and sustainability of these nutritional strategies are also important limitations.

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**This article provides an in-depth look at the structure of chronic inflammation and its effects on health.**

55. •• Li R, Zhan W, Huang X, Zhang Z, Zhou M, Bao W, et al. Association of dietary inflammatory index and metabolic syndrome in the elderly over 55 years in Northern China. *British Journal of Nutrition*. 2022. <https://doi.org/10.1017/S0007114521004207>.

**This article summarizes dietary inflammatory index in the elderly over 55 years.**

**Abbreviations** AD: Alzheimer's disease; BMI : Body Mass Index; CHD: Chronic heart disease; CRP: C-reactive protein; CVD: Cardiovascular diseases; DII: Dietary Inflammatory Index; IL: Interleukin; LDL: Low-Density Lipoprotein; MetS: Metabolic syndrome; NF- $\kappa$ B: Nuclear Factor Kappa  $\beta$ ; SASP: Senescence-associated secretory phenotype; TNF- $\alpha$ : Tumor Necrosis Factor-alpha; TGF- $\beta$ : Transforming growth factor-beta; T2DM: Type 2 diabetes; VLDL: Very Low-Density Lipoprotein

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**Conflict of Interest** The authors declare no competing interests.

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