Racial Differences in Pain, Nutrition, and Oxidative Stress

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ABSTRACT

Investigating the disproportionate rates of chronic pain and their related comorbidities between Black and non-Hispanic White (White) individuals is a growing area of interest, both in the healthcare community and in general society. Researchers have identified racial differences in chronic pain prevalence and severity, but still very little is known about the mechanisms underlying them. Current explanations for these differences have primarily focused on socioeconomic status and unequal healthcare between races as causal factors. Whereas these factors are informative, a racial gap still exists between Black and White individuals when these factors are controlled for. One potential cause of this racial gap in chronic pain is the differences in nutrition and dietary intake between groups. Certain foods play a key role in the inflammatory and oxidative stress pathways in the human body and could potentially influence the severity of the pain experience. Here, we review the previous literature on the surrounding topics and propose a potential mechanism to explain racial differences in the chronic pain population, based on established racial differences in diet and oxidative stress.

Keywords: Race; Diet; Pain; Inflammation; Oxidative stress

Key Summary Points

- There are identified racial differences in pain experience.
- Dietary intake and metabolic responses may differ between racial groups.
- Specific foods and food components have direct and indirect effects on inflammation.
- Oxidative stress as a result of different diet may be the mechanism underlying racial differences in pain.

INTRODUCTION

The prevalence of chronic illness is increasing with an aging population, leading to higher healthcare costs and increasing morbidity for these populations [1]. As a consequence, there is a growing interest in chronic pain [2, 3], a
disease state that has tremendous impact on quality of life, health, and socioeconomic conditions [4, 5]. Chronic pain is defined as any pain that is recurrent or long lasting—typically 6 months or more [6]. It is a unique experience, with complex biopsychosocial pathology, and has very burdensome effects on both physical and mental health. While chronic pain can, at times, develop from an initial injury or insult, it is not simply an extension of acute pain and requires different diagnostic and management strategies [7]. Attempts to treat this disease state have primarily relied on pain-masking pharmaceuticals. Analgesics have demonstrated efficacy in relieving pain, but the healthcare community is now facing an epidemic as more and more people per year die due to overdose or complications with these drugs, particularly the opioids [8–11]. This social crisis has prompted providers and researchers alike to investigate whether there are treatments that exist that relieve pain but do not have the costly side effects of current therapies. Unfortunately, the burden associated with pain does not fall equally on all groups.

To alleviate differences in chronic pain, the underlying mechanisms require elucidation. In addition to racial differences, there are recognized differences in pain that are related to sex and age. There are significant differences in pain threshold and tolerance between the males and females [12–14], with females reporting increased sensitivity and greater likelihood of developing a chronic pain disorder [15]. Older individuals are also at a higher risk for development and increased severity of painful disorders [16]. There are multiple explanations for these phenomena: genetic and hormonal differences in brain neurochemistry, immune system differences, social and cultural expectations of societal roles, and differences in coping strategies [17].

Of particular importance to this review is the disparity between races with respect to pain. In general, race is derived from biological dispositions; however, it is important to note that there are both biological and social components of race that play pivotal roles in the lives of individuals. Early medical research failed to include Black individuals in experiments [18], and it was not until the shift in civil rights that racial differences in pain were first documented by Chapman and Jones in 1944 [19]. Since that time, racial disparities have been documented in many works, revealing that Black individuals disproportionately carry the burden of chronic pain in comparison to their non-Hispanic White (White) counterparts [20–24]. Although the underlying mechanisms for the disparity are unclear, the fact that clinical pain is more prevalent in the Black population is well beyond doubt.

Racial differences in pain are thought to exist for many reasons: genetic predispositions [25]; differences in psychosocial and cultural factors between the two groups [26]; reported differences in coping strategies between races [27]; disparities in healthcare systems and providers [4]; and finally, differences in diet [28]. We [29–31] and others [32–36] have shown that diets varying in nutritional quality affect the outcome of the pain experience. For example, a high-carbohydrate diet can result in systemic inflammation, immune cell activation, and prolonged recovery from injury [29, 37]. On the other hand, a diet low in carbohydrates can promote recovery from injury [29] and reduce daily and evoked pain [38]. Knowing that nutritional quality affects pain and that there are reported differences in dietary consumption of food [39] and documented differences in inflammatory processes (including oxidative stress) between racial groups [40], it is possible that the differences in the diet between Black and White individuals is a major contributing factor to the differences seen in the rates of chronic pain. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

RACIAL DIFFERENCES IN PAIN

Differences in pain between racial groups have been documented in clinical and experimental research [41, 42] and overwhelmingly report that Black individuals are indeed at an increased risk for developing a chronic pain condition, consistently reporting higher incidence rates.
and greater burden [43]. Common types of pain conditions are outlined below.

Emergency Medicine and Postoperative Pain

Pain is one of the most common complaints seen in emergency departments (EDs) across the United States [44]. Over the past two decades, several reports have documented that Black individuals are at risk for undertreatment of pain compared to White individuals. Even when medical conditions are equated, Black individuals are less likely to receive adequate pain medication [45]. It should be noted that these data are often based on ED and postoperative analgesic administration to patients, as opposed to functional pain measures. Using analgesic administration as the primary measure can be problematic, as it is possible that internal bias of the provider may directly affect the amount of medication administered to the patient. Many investigations, including the National Hospital Ambulatory Medical Care Survey (NHAMCS), report evidence suggesting racial differences in pain medication administration by physicians in the ED for specific painful conditions [46–49], while others have reported no differences [50–54]. In studies examining pain after surgery, Black individuals report more pain and pain-related symptoms than White individuals after surgeries to correct scoliosis [55] and dental issues [56] and to manage breast cancer [57]. Despite the expressed need for analgesics, Black patients experienced more severe pain and more pain-related interference, but were less likely to be prescribed pain medication despite their pain rating compared to White patients [58–60]. In an attempt to eliminate the provider bias, researchers have sought to examine patient-controlled analgesia (PCA). However, there are limited studies that report powerful results. Unequal treatment of pain between Black and White individuals can result in significant disparities between groups, but it is possible that there are racial differences in the experience of pain that are independent of medication use/availability. Studies with reasonable sample sizes of patients and better study quality are needed to truly understand differences in this area and provide possible mechanisms.

Chronic Non-Cancer Pain

There are well-documented studies involving racial disparities between Black and White individuals in chronic pain populations [61–64]. White individuals are more likely to report temporomandibular joint (TMJ) and neck pain [65], and facial and jaw pain symptoms than Black individuals, but they appear to have an earlier onset [66]. Although Black individuals report fewer TMJ symptoms, the pain has a greater impact on their daily functioning/tasks [67]. Fibromyalgia appears to affect both Black and White individuals [68]. However, White individuals tend to report significantly increased tenderness in specific areas, while Black individuals report more widespread pain and depressive symptoms [69], once again supporting the notion that the experience of chronic pain conditions differs between races. Black individuals also report more pain and disability than White patients related to chronic low back pain [70] and angina [71]. It has been reported that Black individuals are more likely to express increased pain severity, depression and anxiety, pain-related fear and pain-related disability [72], and a greater sense of suffering and loss of control compared to White individuals [4, 18, 61–64, 73]. Black individuals with chronic knee or hip pain also report a lower quality of life [74]. Regardless of the condition, research suggests that the Black population is at greater risk for increased pain severity, pain-related disability, and inadequate pain management [4, 72].

Arthritis Pain

Arthritis is one of the most common manifestations of chronic pain and one of the leading causes of disability in the United State [75, 76]. According to the National Health Interview Survey, although Black and White individuals had similar rates of arthritis, Black individuals reported much more severe pain in the affected
Research has also revealed that Black individuals demonstrate more severe pain and disability due to osteoarthritis than their White counterparts [78, 79]. One non-biological factor that has been considered to underlie differences in the rates of arthritis-related pain between races is the differences in the rates of knee and hip replacements. Studies on large populations of patients, as well as data from national surveys, show that Black individuals are less likely to receive a joint replacement despite demonstrating a need for the procedure [80, 81]. In individuals with rheumatoid arthritis, Black individuals are likely to have a higher score than White individuals on the Clinical Disease Activity Index, a common tool used to assess rheumatological disease severity and symptoms [82]. There is no clear link between increased disease activity and subsequent increases in pain. However, those with higher disease activity were more likely to be physically debilitated by rheumatoid arthritis [83].

Cancer Pain

A large number of those being treated for cancer live with pain [84], often caused by an injury to the nerves during surgery [85–88] and chemotherapeutic agents that are neurotoxic [89–91], as well as radiation-induced nerve damage [92] and radiation-induced inflammation [93–95]. According to the World Health Organization (WHO), 62% of racial minorities were undertreated for pain in accordance with the WHO standard for cancer-free pain [96, 97]. The same pattern was evident in studies analyzing quality of care: cancer patients who were treated in settings that cared mainly for minorities were more likely than White individuals to receive inadequate analgesics [98, 99].

Experimental Pain

It is very possible that differences in sensitivity to noxious stimuli can underlie racial differences in pain. Several studies have demonstrated differences in pain sensitivity between Black and White individuals, as reviewed by Edwards et al. [18]. Generally, evoked pain ratings are of greater magnitude in Black individuals [100, 101], and this same group shows lower tolerance for experimental pain [102]. When completing heat pain tasks, Black individuals demonstrate significantly lower pain tolerances and thresholds and report pain at lower temperatures than White individuals [19]. Black individuals are also more likely to rate the thermal pain as more unpleasant [103] and report lower tolerance to ischemic pain (pain due to a lack of blood oxygen in the extremities) [104] and lower thresholds and tolerance to cold stimuli compared to White individuals [105]. In two studies examining mechanical pressure pain, Black individuals demonstrated lower pain threshold and tolerance compared to White individuals [101, 104]. Black research participants also report reduced pain tolerance to electrical stimulation pain, and increased temporal summation of noxious stimuli [106]. Taken together, results of experimental pain studies have demonstrated consistent evidence regarding racial differences in pain sensitivity between Black and White individuals.

RACIAL DIFFERENCES IN DIET

There is evidence that nutritional intake varies substantially between racial groups, and there are a variety of factors that are known to underlie the relationship between race and dietary habits. Geographic residence is one such factor thought to play a significant role in dietary behaviors. In many cities, a higher percentage of Black individuals live in low-income environments compared to their White counterparts [107]. Neighborhood disadvantage is associated with poorer diet quality [108] and is correlated with excess meat intake and limited consumption of fruits, vegetables, and fish [109]. For those individuals living in low-income environments, access to supermarkets may be limited compared to those living in high-income environments. This notion of food deserts—areas where residents have little to no access to healthy and affordable food options—is also more often reported in Black neighborhoods [110]. In addition, these areas are more
likely to report lower quality and a limited selection of foodstuffs [111]. As a result, individuals in low-income neighborhoods are likely to increase their consumption of energy-dense, low-cost items in order to ensure adequate food intake [112, 113]. In addition to the lack of fresh produce, the proportion of fast food restaurants to residents is higher in Black neighborhoods [110]. Research has shown that even wealthy, college-educated Black individuals may feel marginalized and live in neighborhoods with 30% less income compared to White neighborhoods, creating a barrier even today [114].

The REasons for Geographic and Racial Differences in Stroke (REGARDS) study provides further evidence that an individual’s racial group may be an influential factor in determining food choice. Adherence to plant-based dietary habits (i.e., vegetables of many types, fish, soups) were positively associated with socioeconomic status (SES), showing that White individuals were more likely to stick to a plant-based diet. By contrast, stronger adherence to a “Southern dietary pattern” (i.e., fried food, soda, and processed meats) was reported more among Black respondents [39]. We recently reported a cross-sectional study of the REGARDS data in which we demonstrate that higher adherence to poor-quality diets (including the “Southern” dietary pattern) was associated with an increased relative risk of reporting pain, whereas high adherence to the plant-based dietary pattern was associated with reduced risk for pain [115]. Together, these data support the notion that racial differences in dietary patterns may contribute to racial differences in the risk for and expression of chronic pain in an American sample.

Taste perception is another important factor that appears to vary between races. Current data suggest that there are differences in taste responsiveness, which can alter the perceived taste of foods such as vegetables. Genetics plays a major role in the perception of taste and was first studied in terms of taste blindness [116]. Individuals with variations in the genes that code for structures responding more intensely to bitter tastes are more likely to avoid fruits and vegetables [117–119]. Variation in sweet taste is also known to correlate with vegetable preference [120, 121]. Although there are limited studies of taste differences among racial groups, it has been reported that Black individuals rate taste sensations such as sweet, salty, and bitter at a higher intensity than White individuals [122]. Taken together, it is possible that genetic differences in taste responsiveness alter the intake of certain foods and may explain differences in food/vegetable intake among these racial groups. Recognizing that there is a difference in sensory experience is important, as it may contribute to an individual’s ability to comply with a diet and explain why people gravitate toward or away from certain types of foods, which can have both beneficial and detrimental effects on health through inflammatory pathways.

DIET AND OXIDATIVE STRESS

Oxidative stress is a biological phenomenon that occurs when there is an imbalance between free radical compounds, such as reactive oxygen species (ROS) or reactive nitrogen species (RNS), and antioxidant defense systems in the body [123–125]. This imbalance leads to the destruction of cells and molecules, impacting the whole system [126]. ROS are a normal byproduct of cellular metabolism of molecular oxygen [127, 128], have important roles in many signaling pathways, and aid in the response to change in internal and external environmental conditions [127–130]. Sustained stress creates excessive ROS, creating an environment with high levels of free radicals causing damage to cellular components that can ultimately lead to apoptosis [131]. Oxidative stress and free radicals have been implicated in a host of degenerative conditions including Alzheimer’s disease [132], Parkinson’s disease [133, 134], cardiovascular disease [135, 136], cancer [137, 138], chronic inflammation [139, 140], and diabetes [131, 141]. Oxidative stress can be triggered by many sources and is heavily influenced by dietary quality.

Diet types such as the standard American diet (SAD) [29, 30] that are rich in processed carbohydrates and saturated fats contribute to increased postprandial oxidative stress and a
chronically elevated state of oxidative stress [142–146]. A poor-quality diet creates an environment of oxidative stress by increasing the presence of free radicals, reducing antioxidant status and resulting in cell damage [147]. Glucose oxidation is thought to be the main source of free radicals via the diet [131]. Glucose can be oxidized to a superoxide anion radical leading to the production of extremely reactive ROS and RNS if it is not degraded by an antioxidant [148–153]. ROS and other free radicals have also been linked to metabolic imbalances in neural tissues leading to impaired neurotropism [154–156], changes in neurotransmission [157–159], Schwann cell injury [160, 161], and axonopathy [162, 163]. Excess carbohydrates are also known to promote lipid peroxidation of low-density lipoprotein (LDL cholesterol) via superoxide-dependent pathways, which also participates in the generation of free radicals [164, 165]. Finally, a high-carbohydrate diet can lead to the production of advanced glycation end products (AGEs) [166] through glycation: a reaction between excess carbohydrates in the body and other nutrients like lipids, proteins, and nucleic acids [167–171]. These compounds exert their deleterious effects by binding to the receptor for AGEs (RAGE) [167, 172] and stimulating various intracellular signaling pathways [173], which leads to apoptosis, inflammation [174, 175], and cell differentiation. This activation can also inhibit a number of enzymes by altering their structures and functions [176], promote free radical formation [177, 178], and prevent antiproliferative effects of nitric oxide from occurring [179, 180].

In addition to increasing the presence of free radicals in the body, excess carbohydrates also impair the innate antioxidant defense system. Under normal conditions, antioxidants are able to neutralize free radicals and prevent them from creating cellular damage and oxidative stress [181–183]. For example, vitamin E prevents the progression of lipid peroxidation; vitamin C alongside vitamin E prevents hydroperoxides from forming; transition metals, such as copper and zinc, are involved in the inhibition of lipid peroxidation; and vitamins A and E are also considered “scavengers” as they seek out and neutralize free radicals [151, 178, 184–187]. A summary of the most common antioxidants and their sources can be seen in Table 1. A diet with excess carbohydrates can create a surplus of free radicals that overwhelm the innate antioxidant system, increasing oxidative damage. Furthermore, many poor-quality diets that are high in carbohydrates tend to be vitamin-deficient [188], further reducing the ability of the body to control free radicals.

**OXIDATIVE STRESS AND PAIN**

There is emerging evidence suggesting that oxidative stress is involved in the development and maintenance of pain. Although oxidative stress can be caused by many factors such as smoking, excess alcohol consumption, air pollution, and UV light, it is also sensitive to foodstuffs and is directly affected by the meal components [143]. There are studies attributing poor-quality diet to increased pain sensitivity [29–31, 38], possibly through increased oxidative stress. Black individuals are at higher risk for elevated oxidative stress levels [189] and, as previously discussed, are more likely to adhere to a diet pattern that includes excess carbohydrate consumption [39]. Additionally, oxidative stress has been linked to many types of painful conditions, which are often reported at higher rates in Black populations [40]. It may be possible that diet variability influences the differences seen in the prevalence and severity of painful conditions amongst Black and White patients. However, the direct link between oxidative stress and pain is not clearly understood. It is important to note that oxidative stress may contribute to pain in different pathological modalities, all of which are important in the pain experience.

**Inflammation**

Inflammation is induced by many biochemical and physical factors such as infection, injury, allergens, and radiation, as well as diet-induced oxidative stress [126, 190, 191]. Chronic inflammation predisposes an organism to various chronic illnesses [192], including chronic
Table 1 A summary of the most common antioxidants, their reported mechanism of action, sources, and citation(s)

| Antioxidant       | Mechanism of action | Food sources                                      | References                                           |
|-------------------|---------------------|--------------------------------------------------|-----------------------------------------------------|
| Vitamin C         | Nonenzymatic        | Broccoli, oranges, Brussels sprouts, tomatoes, and leafy green vegetables | Block et al. [214], Levine et al. [215], Padayatty et al. [216] |
| Vitamin A         | Nonenzymatic        | Eggs, spinach, carrots, cod liver oil, and leafy green vegetables | Block et al. [214], Block [217]                      |
| Vitamin E         | Nonenzymatic        | Wheat germ, nuts, seeds, avocado, fish, leafy green vegetables | Murphy et al. [218], Reboul et al. [219]             |
| Glutathione       | Nonenzymatic        | Endogenous                                        | Meister [220], Sies [221]                           |
| Superoxide        | Enzymatic           | Endogenous                                        | Halliwell [222], Clarkson et al. [223]              |
| Glutathione       | Enzymatic           | Endogenous                                        | Flohe [224], Clarkson et al. [223]                  |
| Catalase          | Enzymatic           | Endogenous                                        | Betteridge [225], Chelikani et al. [226]            |
| Glutathione       | Enzymatic           | Endogenous                                        | Halliwell [222], Clarkson et al. [223]              |
| Lipoic acid       | Nonenzymatic        | Nuts, seeds, Brussels sprouts, organ meats, red meat | Shay et al. [227], Rochette et al. [228]             |
| Carotenoids       | Nonenzymatic        | Carrots, plums, apricots, mangoes, cantaloupe, and sweet potatoes | Clarkson et al. [223], Rao et al. [229]             |
| Coenzyme Q10      | Enzymatic           | Endogenous, organ meats, pork, beef, chicken, fish, leafy green vegetables, strawberries, beans, nuts, and seeds | Pravst et al. [230]                                  |
| Bioflavonoids     | Nonenzymatic        | Oranges, lemons, apples, and legumes              | Cook [231]                                          |
| Copper            | Nonenzymatic        | Whole grains, green beans, nuts, potatoes, shellfish, and organ meats | Keis [232]                                         |
| Zinc              | Nonenzymatic        | Whole grains, milk and milk products, red meat, chicken, beans, and nuts | Solomons [233]                                     |
| Manganese         | Nonenzymatic        | Beans, seeds, nuts, whole grains, leafy green vegetables, and soybeans | Black et al. [234]                                  |
| Selenium          | Nonenzymatic        | Whole grains, milk and milk products, pork, beef, turkey, fish, chicken, shellfish, eggs, and mushrooms | Rayman [235]                                        |
| Folic acid        | Nonenzymatic        | Whole grains, rice, oranges, leafy green vegetables, and beans | Dietrich et al. [236], Looman et al. [237]          |
| B Vitamins (B1, B2, B6 and B12) | Nonenzymatic | Pork, chicken, turkey, fish, whole grains, eggs, leafy green vegetables, and soybeans | Scott [238], Banjari et al. [239], Mielgo-Ayuso et al. [240] |
pain. During the peripheral inflammatory response, mast cells and leukocytes are recruited, leading to a subsequent increase in the uptake of oxygen and an increased release and accumulation of ROS. Accumulation of ROS can result in a cellular cycle of events producing pro-inflammatory mediators such as arachidonic acid, cytokines, and chemokines, which recruit more inflammatory cells and molecules that subsequently create more reactive species [189]. In the context of AGES, interaction with RAGE causes the induction of intracellular ROS production through activation of NF-κB (nuclear factor kappa-light-chain-enhancer of activated B cells) and leads to the further production of inflammatory mediators [193]. Many signal transduction cascades and transcription factors have been implicated in oxidative stress pathways, including NF-κB, signal transducer and activator of transcription 3 (STAT3), hypoxia-inducible factor-1α (HIF-1α), nuclear factor of activated T cells, NF-E2 related factor-2 (Nrf2), cyclooxygenase-2 (COX-2), inducible nitric oxide synthase (iNOS), inflammatory cytokines such as tumor necrosis factor (TNF), interleukin-1β (IL-1β), IL-6, chemokine IL-8, and CXC chemokine receptor 4 (CXCR4), as well as alterations in the expression of specific micro-RNAs [126]. These compounds can directly stimulate nociceptors and other afferent neurons, resulting in pain. It has been reported that Black individuals have exaggerated levels of basal oxidative stress and inflammation [189] even in the absence of injury [194]. Taken together, this suggests that dietary makeup may have a greater negative impact on oxidative stress and subsequent pain in this group.

Neuropathy and Neuopathic Pain

Neuropathy—often referred to as peripheral neuropathy—refers to a group of conditions characterized by abnormal function of the nerves in the peripheral nervous system due to damage or disease. Symptoms can range from numbness/tingling to intense neuropathic pain and loss of function [195]. While there are other noted risk factors for neuropathy, such as repetitive movements and injuries or chemotherapy, diet-induced oxidative stress can also exert deleterious effects on the structure and function of nerve cells. In fact, it has been shown that poor glycemic control is an independent risk factor for the development of diabetic neuropathy [196]. At a cellular level, neuronal apoptosis has been shown to occur from exposure to both ROS and RNS [197]. Lipids that are present in various organelles such as the mitochondria, endoplasmic reticulum, and cytoplasm are major targets of ROS damage, and the resulting lipid peroxides can be neurotoxic upon accumulation. Axonal transport of important neurotransmitters, growth factors, and other intermediates can also be slowed in such an environment, which can result in induced apoptosis of the neuron [198]. Resulting increases in AGES can induce a feedforward cascade of progressive neuronal dysfunction and impaired neurotrophic support in the short term, and can cause apoptosis of the whole neuron or injury to supporting cells, such as Schwann cells, that are important in the conduction of nerve signals [199]. Upon neuronal injury, macrophages respond by infiltrating the injured site. Here, they express many surface cell markers and secrete cytokines and chemokines. Macrophages in the periphery work similarly to microglia in the central nervous system [200] to remove cellular debris and dead neurons through Wallerian degeneration, allowing for regrowth of the injured axon (in the periphery) [201]. This process of degeneration and regeneration of the injured cell is hypothesized to be a part of the pathogenesis of neuropathic pain and sclerosis, in addition to the actual dysfunction and neuronal death as a result of oxidative stress [202]. AGES can act as a “danger signal,” much like pathogens or intermediates produced from neuronal apoptosis, activating macrophages without any actual damage [203]. Following priming of peripheral immune cells, it has been observed that, upon stimulation by other danger signals, these macrophages display an exacerbated response, which may contribute to the development of neuropathic pain [204]. According to a 2017 study exploring the prevalence of neuropathic pain in the United States, there was significant
racial variation amongst those who reported these symptoms, with Black individuals representing a much larger percentage of the sample than White individuals, despite being a smaller proportion of the overall population [205]. It is possible that the variation in glycemic load as a result of differing dietary carbohydrate intake could play a significant role in this difference. While neuropathies are known to have heterogeneous etiologies, the acknowledgement of diet-induced oxidative stress is a critical factor to advance our understanding of these conditions.

It is widely accepted that poor-quality diets can be detrimental to one’s health, including potential exacerbation of the pain experience via oxidative stress and inflammation. Therefore, it would be efficacious to explore the effects that higher-quality diets have on the prevention and possible reversal of chronic pain. Dietary interventions for chronic pain have gained traction as a possible alternative treatment modality, and investigations of dietary intake have shown that many individuals with chronic pain have an imbalance in the free radical to antioxidant ratio and that reversing this imbalance can alleviate pain [206]. There is clinical evidence that vitamin C, a common antioxidant found in many fruits and vegetables, may have a protective effect against the development of complex regional pain syndrome (CRPS) through its ability to reduce oxidative stress [207]. Treatment with vitexin (a common flavonoid in plants) for inflammatory injury via phenyl-\(\beta\)-benzoquinone, complete Freund’s adjuvant, formalin, or capsaicin inhibited pain-like behavior in mice. This treatment also lowered oxidative stress and pro-inflammatory mediators, and increased antioxidant capacity and anti-inflammatory compounds [208], demonstrating a potential link between oxidative stress and pain. Supplementation with vitamin B12 has been shown to reduce markers of oxidative stress and inflammation [209], and can lead to reductions in pain scores and use of analgesics in patients with low back pain [210]. Furthermore, it has been suggested that consuming 1000 \(\mu\)g/day may improve symptoms of pain [211]. Curcumin, the active ingredient in the spice turmeric and black pepper, has also been shown to act as an antioxidant, reduce oxidative stress, and improve pain caused by diabetic neuropathy [212]. These exploratory studies have expanded the body of evidence supporting the use of food for treatment of painful conditions. However, more work needs to be done to understand the efficacy of these foods and supplements across racial groups.

**CONCLUSION**

Racial differences in chronic pain prevalence and burden of the pain exist, in that Black individuals are disproportionately affected [20–24]. This racial group has higher rates of most chronic pain conditions, but also report more severe and intense pain compared to their White counterparts [106]. There are many possibilities as to why these differences are observed—genetics, psychosocial variables, and unequal care [4, 25–28]. In addition, differences in diet patterns between the two racial groups [39] is an important factor that has been overlooked in this area of research. Of particular importance is the variability between the amount of carbohydrates and unhealthy fats consumed within each racial group [213]. Black individuals consume significantly more of these macronutrients, even when controlling for other factors influencing diet [39, 108, 110]. Carbohydrates can increase oxidative stress [143–146], perhaps resulting in the observed elevated levels of systemic inflammation [126] and oxidative stress [189] in Black populations when compared to White populations. Therefore, variability in food intake between racial groups may underlie racial differences in chronic pain. We have shown that a diet intervention can reduce pain and oxidative stress [38], but it is possible that a reduced carbohydrate diet has greater benefit based on racial group. Thus, it is encouraged that future studies aim to further understand the relationship between diet, oxidative stress/inflammation, and pain outcomes across races. Dietary interventions and nutritional education are safer, more modifiable treatments with less risk of negative side effects and other complications,
which may limit the reliance on opioid analgesics. Most critically, dietary interventions may provide a means to reduce racial differences in chronic pain.

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