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THE RELATIONSHIP BETWEEN HIGH GLYCEMIC INDEX DIET AND MUSCULOSKELETAL DISORDERS

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ABSTRAK

Gangguan muskuloskeletal mencakup kondisi akut maupun kronis yang memengaruhi otot, tulang, sendi, dan struktur pendukung di leher, punggung, dan anggota badan, yang menimbulkan tantangan signifikan di semua jenjang usia dimana sekitar 30% kasus terjadi pada usia remaja dan produktif, bukan hanya pada lansia. Hal ini menyebabkan beban sosial ekonomi dan kesehatan yang substansial. Penelitian terdahulu menunjukkan bahwa pola makan memainkan peran penting dalam timbulnya dan perkembangan gangguan ini. Pola makan indeks glikemik (IG) tinggi yang terus menerus telah dikaitkan dengan peradangan sistemik, disregulasi metabolik, dan kesehatan muskuloskeletal. Studi ini bertujuan untuk memberikan tinjauan komprehensif dari literatur yang ada untuk merangkum dan mengidentifikasi hubungan potensial antara diet Indek glikemik tinggi dengan prevalensi MSD. Artikel dikumpulkan dengan menggunakan mesin pencari seperti *Pubmed, Medscape*, dan *Science Direct* yang diterbitkan pada tahun 2013-2024. Penelitian ini menyoroti pentingnya intervensi diet sebagai faktor resiko yang dapat dimodifikasi untuk mencegah dan mengelola gangguan muskuloskeletal, khususnya pada populasi beresiko. Studi lebih lanjut diperlukan untuk strategi diet dalam mengurangi beban global gangguan muskuloskeletal secara efektif.

ABSTRACT

The Relationship Between High Glycemic Index Diet and Musculoskeletal Disorders. Musculoskeletal disorders include acute and chronic conditions affecting the muscles, bones, joints, and supporting structures in the neck, back, and limbs, posing significant challenges across all age groups. Approximately 30% of cases occur in adolescents and individuals in their productive years, not just in the elderly. These disorders lead to substantial socioeconomic and health burdens. Previous research indicates that dietary patterns play a critical role in the onset and progression of these conditions. A persistent high-glycemic index (GI) diet is associated with systemic inflammation, metabolic dysregulation, and musculoskeletal health. This study aims to provide a comprehensive review of existing literature to summarize and identify the potential relationship between high-GI diets and the prevalence of musculoskeletal disorders (MSDs). Articles were collected using search engines such as PubMed, Medscape, and ScienceDirect, focusing on publications from 2013 to 2024. The findings emphasize the importance of dietary interventions as modifiable risk factors for preventing and managing musculoskeletal disorders, particularly in at-risk populations. Further studies are needed to develop dietary strategies to reduce the global burden of musculoskeletal disorders effectively.

INTRODUCTION

Musculoskeletal disorders (MSDs) encompass both acute and chronic complaints of the musculoskeletal system, including muscles, bones, joints, ligaments, nerves, and other structures that support the neck, back, and limbs. These complaints can range from mild to severe in intensity.[1,2,3] Beyond their physical impact, musculoskeletal disorders often have profound effects on the mental and emotional well-being of sufferers, further amplifying their burden.[4,5,6] Consequently, MSDs significantly diminish the quality of life while also exerting a substantial socio-economic toll on individuals and their communities.

Musculoskeletal disorders are most frequently observed in the elderly due to aging-related cellular and tissue degeneration. They also affect younger populations.[7,8] Global data indicate that MSDs contribute to 42–58% of work-related diseases globally and account for 40% of healthcare costs in the workforce.[7,9] Additionally, 30–34% of MSD cases occur in adolescents, influenced mainly by physical activity, posture, and daily lifestyle choices such as nutrition.[2,8] Recognizing the critical role of diet, the World Health Organization (WHO) emphasizes the importance of proper nutrition in supporting musculoskeletal health.[10] Adequate nutritional intake has been shown to aid the body in managing injuries and muscle fatigue, largely through its effects on the immune system's capacity to repair tissue damage.[11,12,13]

Previous studies have identified a significant association between oxidative stress and the development of musculoskeletal disorders, including fibromyalgia and vertebral discus degeneration.[14,15] These conditions are often attributed to elevated levels of free radicals and systemic inflammation, exacerbated by consuming excessive high-glycemic index diets.[16,17,18] The glycemic index, a measure of how quickly carbohydrates raise blood glucose levels, is categorized into three groups: low (<55), medium (55–70), and high (>70).[19,20] High-GI diets result in rapid fluctuations in blood glucose levels, a phenomenon often described as the "roller coaster effect", which can lead to chronic hyperglycemia.[12,21] Prolonged exposure to elevated blood glucose levels promotes advanced glycation end product (AGEs) accumulation in various tissues throughout the body.[22,23]

The accumulation of AGEs has been shown to exacerbate inflammation and oxidative stress within affected tissues.[24,25,26] For example, in the musculoskeletal system, AGEs are linked to reduced muscle strength, increased fatigue, and delayed recovery of damaged cells and tissues.[11,13,22,27] This study aims to explore the impact of high-glycemic index diets on musculoskeletal disorders, focusing specifically on their role in promoting inflammation and oxidative stress.

METHOD

The method employed in this study involved a systematic literature review using the keywords “Glycemic Diet,” “Musculoskeletal Disorders,” and “Oxidative Stress.” The search was conducted through the PUBMED, Medscape and Science Direct database, with inclusion criteria comprising articles published between 2013 and 2024, full-text availability, original research or review articles, and publications in English. The review process included the following steps: (1) conducting a keyword-based search adhering to the specified criteria, (2) removing duplicate entries, (3) screening articles by evaluating their titles and abstracts, (4) extracting data by assessing the relevance of article titles to the study objectives, and (5) analyzing and synthesizing the content of selected articles. Ultimately, seven articles were identified as relevant, highlighting that poor

dietary habits, such as consuming high-glycemic index foods, can elevate oxidative stress and inflammation, which are critical contributors to musculoskeletal disorders.

Table 1. Summary of research articles about high glycemic index diet to musculoskeletal disorders

Researcher and year of publication	Type of research	Research conclusion
Juanola et al., 2014	RCT	A low GI diet containing moderate carbohydrates may be more effective in controlling glucose, inflammation, and other degenerative and metabolic risk factors than a high GI diet.[16]
Jiang et al., 2022	RA	AGE accumulation can occur through endogenous or exogenous sources. Exogenous AGEs are found in various types of foods. The binding of AGEs to their receptors (RAGE) can cause activation of various cascades that trigger inflammation and oxidative stress.[22]
Eleftheria et al., 2020	RA	Poor diet can trigger hyperglycemia, resulting in the formation of advanced glycation end products (AGEs), activation of protein kinase C (PKC), and hyperactivity of the hexosamine and sorbitol pathways, leading to the development of insulin resistance, impaired insulin secretion, and endothelial dysfunction, by inducing excessive ROS production that triggers oxidative stress and inflammation.[28]
Elma et al., 2020	RA	Pain severity is positively associated with sugar intake in chronic osteoarthritis pain. Plant-based dietary patterns such as vegetarian and vegan diets might have pain-relieving effects on chronic musculoskeletal pain.[11]

Assavarittirong et al., 2022	RA	Oxidative stress is a factor in the occurrence of musculoskeletal problems such as rheumatoid arthritis and fibromyalgia.[14]
Larissa et al., 2022	RA	Carbohydrates can increase oxidative stress and result in elevated levels of systemic inflammation and oxidative stress. Thus, Diet intervention can reduce pain and oxidative stress.[18]
Hendrix et al., 2022	RA	Oxidative stress has been studied in relation to pain. Epigenetic mechanisms and ANS function appear to mediate the relationship.[29]
Cirillo et al., 2023	RA	There is a relationship between pain reduction and relief with dietary patterns such as the Mediterranean diet, which contains many vegetables.[30]

DISCUSSION

Blood Glucose Levels and Glycemic Index

Glucose is the main source of energy for human cells.[18,31] Glucose is formed from carbohydrates consumed through food and stored as glycogen in the liver and muscles. Blood glucose is the glucose level in the blood whose concentration is tightly regulated by the body. Glucose flowing in the blood is the body cells' main energy source. Generally, blood glucose levels remain in the range of 70-150 mg/dL, and there is an increase in blood glucose levels after eating. It is generally at its lowest level in the morning before consuming food.[12] An increase in blood glucose levels after eating or drinking will stimulate the pancreas to produce insulin, preventing further increases in blood glucose levels and causing blood glucose levels to decrease slowly.[32,33] Blood glucose is the main nutrient used for cell metabolism and energy supply in the body, as well as regulating and maintaining glucose within normal limits.[18,33]

Wolever et al., explain that individuals who consume a low GI diet have lower postprandial glucose levels compared to individuals who consume a high GI diet.[34] This shows a close relationship between eating high-GI foods and increased blood sugar.[35] Food intake models that increase blood glucose levels quickly have a high Glycemic Index (GI).

High GI foods produce a rapid increase in blood glucose levels. The more high-glycemic foods are consumed, the faster they trigger postprandial hyperglycemia and the longer they trigger increased insulin resistance and pancreatic beta cell dysfunction.[3,36] In addition, postprandial hyperglycemia is also followed by postprandial hyperlipidemia, which will trigger the accumulation of free radicals in the body so that there is an imbalance of free radicals, which eventually causes

oxidative stress.[18,31] Therefore, reducing the consumption of high-GI foods can reduce hyperglycemia and postprandial hyperlipidemia and prevent the risk of oxidative stress.

The Glycemic Index (GI) is a numerical system that ranks carbohydrate-containing foods based on their effect on postprandial blood glucose levels. Foods are classified into three categories: low, medium, and high GI. Low GI foods, with a value less than 55, are digested and absorbed slowly, leading to a gradual rise in blood glucose levels. This results in sustained energy release and a minimal insulin response, making them beneficial for maintaining steady blood sugar levels. Medium GI foods, with a range of 55 to 70, are digested and absorbed at a moderate rate, producing a stable energy supply and a moderate insulin response. High GI foods, with a value greater than 70, are rapidly digested and absorbed, causing a sharp spike in blood glucose followed by a rapid decline. This triggers a significant insulin response, which can promote fat storage, increase hunger, and elevate the risk of weight gain and degenerative disease such as musculoskeletal disorder. [19,28,37]

Mechanism of AGEs causing Oxidative Stress and Inflammation

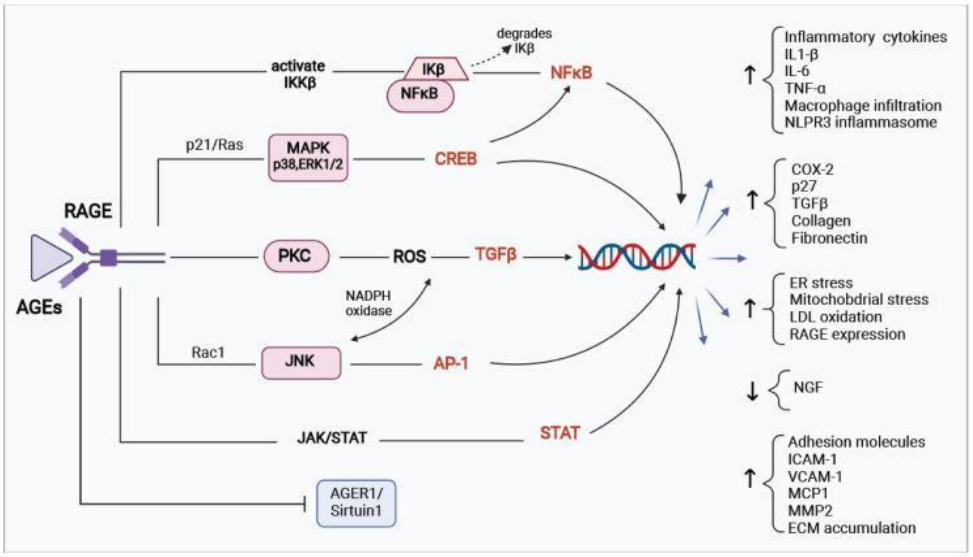

Figure 1. AGEs/RAGE interactions activated multiple cascades.[22]

In figure 1 illustrates how the interaction between advanced glycation end products (AGEs) and their receptor (RAGE) activates various signalling pathways, including NF-κB (nuclear factor kappa B), PKC (Protein Kinase C), MAPK (mitogen-activated protein kinases), and JAK/STAT (Janus kinase-signal transducer and activator of transcription). These pathways collectively contribute to heightened inflammatory responses and oxidative stress.[22] Oxidative stress arises from an imbalance between oxidants and antioxidants in the body, often caused by elevated levels of free radicals such as reactive oxygen species (ROS) and reactive nitrogen species (RNS).[38] While ROS can act as signalling molecules that regulate apoptosis and prevent uncontrolled cell growth.[27,38,39] Chronic and excessive ROS production can adversely impact the musculoskeletal system, leading to muscle fatigue and other disorders.[27,40]

ROS and RNS, when present in controlled amounts, play a critical role in muscle function by activating AMPK (AMP-activated protein kinase), facilitating glucose uptake and energy (ATP) production.[27,40,41] However, sustained overproduction of ROS/RNS can have detrimental effects. Prolonged activation of AMPK may overstimulate CREB (cAMP-response element binding protein), leading to mitochondrial dysfunction, increased production of pro-inflammatory cytokines, and an

extended recovery period for damaged tissues.[22] Excess ROS/RNS levels, often linked to the continuous accumulation of AGEs due to high glycemic index (GI) diets without adequate antioxidant intake, exacerbate musculoskeletal health problems.[22,37] This underscores the importance of dietary balance and the inclusion of antioxidant-rich foods to mitigate oxidative stress.

The World Health Organization (WHO) highlights nutrition as a pivotal factor for musculoskeletal health.[10] Accumulation of AGEs is not confined to musculoskeletal tissues but can also occur in other organs, such as the digestive system. AGE deposition in the gastrointestinal tract may impair intestinal integrity and enzyme function, further triggering systemic inflammation.[22,41] Moreover, AGE accumulation in blood vessels can lead to increased collagen deposits, disrupting elastic fibre organization and degenerating smooth muscle tissue. These mechanisms contribute to vascular dysfunction and may exacerbate musculoskeletal conditions.[22]

Although advanced glycation end products (AGEs) can originate from both endogenous and exogenous sources, such as metabolic byproducts of cellular respiration (endogenous), the primary contributor to AGE accumulation is dietary intake (exogenous). When consumed in excessive and sustained amounts of high glycemic index foods, it significantly promotes hyperglycemia, thereby accelerating the formation and accumulation of AGEs in the body. Without proper countermeasures, such as regular exercise, adequate rest, effective stress management, and exogenous antioxidant intake derived from sources such as vegetables, fruits, and antioxidant supplement, plays a critical role in mitigating oxidative damage and modulating the inflammatory response. These antioxidants enhance the body's defense mechanisms by neutralizing free radicals and reducing the harmful effects of oxidative stress.[16,27,29]

Oxidative Stress and Inflammation cause Musculoskeletal Disorders

Musculoskeletal disorders are generally in the form of pain. Pain in musculoskeletal disorders often does not describe the tissue damage that occurs.[16,23] Therefore, most musculoskeletal disorders in the form of pain are often ignored and are at risk of worsening in the future and even resulting in disability.[2,3] Pain perception involves a series of complex physiological processes. It begins with transduction, where specialized pain receptors in tissues like the skin, muscles, and bones detect noxious stimuli such as injuries, burns, or ischemia, generating pain signals. These signals are transmitted through two types of nerve fibers: A fibers, which quickly convey sharp and localized pain, and C fibers, responsible for dull, aching sensations. The process then progresses to transmission, during which these pain signals travel from the receptors to the spinal cord, brainstem, and thalamus for further processing. Once the signals reach the brain, perception occurs, transforming the pain into a conscious experience. Different brain regions contribute to this stage: the reticular system triggers physical responses, the somatosensory cortex assesses the pain's characteristics, and the limbic system regulates emotional reactions. Finally, modulation takes place as the pain signals are adjusted on their return journey through the spinal cord. This modulation, which can either amplify or suppress the sensation, is influenced by the release of endogenous opioids, leading to variations in pain experiences among individuals.[1,18,29]

The underlying pain mechanisms in musculoskeletal disorders remain incompletely understood, particularly regarding the specific stages at which they occur. However, evidence from the literature suggests that musculoskeletal pain associated with neuropathic components is one of the most prevalent and disabling conditions within this category. Neuropathic pain arises from

damage or dysfunction in the somatosensory system, encompassing both peripheral and central components.[42,43]

Peripheral sensitization is characterized by an enhanced response of nociceptors following tissue injury, leading to increased pain signalling at the injury site. In contrast, central sensitization involves heightened excitability within the central nociceptive pathways, resulting in an exaggerated or abnormal response to typically innocuous stimuli. These pathophysiological processes contribute to hallmark clinical features of neuropathic pain, including spontaneous pain, allodynia (pain due to stimuli that do not normally provoke pain), and hyperalgesia (increased sensitivity to painful stimuli).[42,44]

The accumulation of AGEs triggers a complex inflammatory process, such as neuroinflammation, which involves the immune response, neurons, and glial cells. Inflammatory signals are transmitted to the supraspinal region through primary afferent fibres that connect to dorsal horn neurons in the ascending pain pathway. Within the brain, glial cell activation releases proinflammatory cytokines, including tumor necrosis factor-α (TNF-α), interleukin 1-beta (IL-1β), and other related cytokines. These molecules sensitize somatosensory neurons, contributing to neurodegeneration, impairing synaptic plasticity, and inhibiting long-term potentiation (LTP) in the hippocampus. Additionally, inflammatory mediators can function as neuromodulators in the spinal cord, promoting synaptic plasticity (e.g., LTP), initiating inflammation, and influencing pain sensitivity.[42,45,46]

CONCLUSION

Prolonged high-GI diets can cause chronic hyperglycemia, leading to AGEs accumulation, which triggers inflammation and oxidative stress. These factors contribute to musculoskeletal degeneration. A low-GI diet with antioxidant-rich fruits and vegetables can reduce oxidative damage, alleviate pain, and slow disease progression, highlighting the importance of balanced nutrition for musculoskeletal and overall health.

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