Review

A systematic review of diet, food, and rehabilitation interventions for chronic musculoskeletal pain in the international classification of functioning, disability, and health (ICF) model

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Abstract. *Background:* To evaluate the effects of dietary modifications and specific food choices on chronic musculoskeletal pain management, using the International Classification of Functioning, Disability, and Health (ICF) model to examine their impact on body function, physical activities, and social participation. *Methods:* This systematic review was conducted from January 2013 to January 2023. A comprehensive literature search across four databases (PubMed, Food Science & Technology Abstracts, ProQuest, and Scopus) yielded 7 randomized controlled trials that met the inclusion criteria. The outcomes measured included pain, inflammation, and quality of life. A Meta-analysis was also employed to explore the overall impact of dietary interventions on pain. *Results:* Most studies showed significant improvements in pain levels following dietary intervention, with variations depending on the specific dietary modifications. The impact on inflammation, as measured by the Erythrocyte Sedimentation Rate and interleukin levels, presented mixed results. However, a positive effect on quality of life was observed in studies combining dietary interventions with physical therapy or exercise. *Conclusion:* The results underscore the potential of integrated approaches to chronic musculoskeletal pain management but indicate that further research is needed to clarify the effects on inflammation and identify optimal dietary strategies for different pain conditions.

Key words: chronic musculoskeletal pain, diet, food

Introduction

Chronic musculoskeletal pain is the leading contributor to disability worldwide. More than 1.71 billion people globally experience musculoskeletal conditions, with low back pain associated with other musculoskeletal conditions representing the majority of disability cases in most parts of the world (1). According to the International Classification of Functioning, Disability, and Health (ICF) model, Chronic musculoskeletal pain has a significant impact on mobility, dexterity, and physical condition, hindering the ability to meet the demands of work and daily life (2). This, in turn, reduces levels of well-being and decreases the capacity to participate fully in society. Chronic musculoskeletal pain is defined as pain that occurs in musculoskeletal tissue and lasts or recurs for more than three months. Chronic musculoskeletal pain can lead to significant functional disability and emotional distress, hindering physical activities and social participation (3). Clauw et al., 2015 reveal the three mechanisms that cause chronic pain: peripheral or nociceptive, peripheral neuropathic, and central neuropathic or centralized pain (4). The peripheral, nociceptive, and neural contributions are important components in chronic musculoskeletal pain which applies to common chronic musculoskeletal pain disorders, including rheumatoid arthritis (RA), osteoarthritis (OA), low back pain (LBP), and fibromyalgia (FM) in the general population (5). Puntillo et al. state that the pathophysiology of musculoskeletal pain involves the peripheral and central nervous systems and includes interactions between neurons and non-neural components such as glial, mesenchymal, and immune cells. Aδ and TrkA+ sensitive C-fibers that innervate bone and muscle, along with adrenergic and cholinergic sympathetic nerve fibers, present in several three-dimensional patterns and differ in densities among structures. These fibers can initiate pain transmission. Inflammation, acid accumulation, and increased pressure are associated with musculoskeletal pain and increase the excitement of Aδ and C-fibers, leading to the body developing a heightened sensitivity to pain (6). Researchers categorize the excitement of Aδ and C-fibers as peripheral hypersensitivity. Peripheral hypersensitivity can impact areas beyond the original site and influence the plasticity of the central nervous system. Psychological, demographic, cognitive, emotional, and socioeconomic factors can also heighten the sensitivity to pain at the molecular level, exacerbating both central and peripheral responses to pain (7). Chronic musculoskeletal pain significantly affects people's quality of life. Individuals with chronic musculoskeletal pain condition often seek care following symptom exacerbation, rather than engaging in preventive services such as diet and food modification before the onset of symptoms. Meanwhile, the healthcare system frequently lacks a comprehensive interdisciplinary approach. Thus, the separation of medical services, such as the distinction between rehabilitation medicine and nutrition intervention, can result in extended rehabilitation periods for patients with chronic musculoskeletal pain. Additionally, there is a notable lack of emphasis on promoting lifestyle modifications, particularly regarding diet and food choices. Dietary change and lifestyle behavior change are hard and take strategies and a commitment that are not always easy to implement. A thorough understanding of chronic musculoskeletal pain should consider aspects of diet, food choices, and the possible biopsychosocial factors contributing to pain conditions. Adopting the proper evidence-based practice could lead to a more integrated approach in diet-related and rehabilitation-related studies (8). Recent research shows that nutritional interventions mainly in dietary modification and food choices, combined with rehabilitation exercises can provide significant relief for patients with chronic musculoskeletal pain (9). At the microbiology level, the nutritional intervention supports the peripheral neural function and enhances the central nervous system's neural plasticity, which helps desensitize the nerves and decreases the level of pain. At the personal and social level, the enhancement of diet and food choices improves health and quality of life and reduces healthcare expenditure (9). A previous systematic review addressed a similar topic primarily emphasizing physical outcomes and with less focus on quality of life and social activities (10). To bridge this gap, our research aims to investigate specific dietary patterns' impact on rehabilitation outcomes within the domains of body structures and functions, as well as activities and participation using the ICF framework (2). The main goal of the study is to review and evaluate the methodological quality and findings of current research that focuses on identifying characteristics of diet, food choices, and rehabilitation that improve chronic musculoskeletal pain across Functioning, Disability, and Health domains.

Method

Study design

The current study is a systematic review of the literature on randomized controlled trials (RCTs). It follows the criteria defined in the PRISMA declaration for the preparation and analysis of systematic reviews (11).

Search strategy

The present study uses four databases for the bibliographic search over the past decade from January 2013 to September 2023 by independent investigators (ZD): PubMed, FSTA Web of Science, ProQuest, and Scopus. The research question followed the description of the components of the PICO strategy (Population: Adults older than 18 years old with musculoskeletal chronic pain conditions; interventions: Dietary modification and specific food choices; Comparison: Standard dietary patterns; Outcome: Improved management of pain and function in rehabilitation, as measured by the ICF model). Based on the guidelines from Medical Subject Headings (MeSH) and Descriptors in Health Sciences dictionaries (DeCS), the present study uses a comprehensive search strategy, shown in Table 1.

Eligibility criteria

The PICO framework, as mentioned, was followed to determine which studies would be included in the present systematic review. Each study had to meet the following inclusion criteria:(i) published from January 2013 to September 2023, (ii) published in the English language and internationally peer-reviewed, (iii) classified as RCTs (iv) full text available, (v) adults over 18 years of age, and (vi) participants had to be suffering from chronic musculoskeletal pain for at least 3 months. The exclusion criteria were studies that (i) did not evaluate chronic pain, (ii) did not apply diet in people with chronic musculoskeletal pain as treatment, and (iii) did not show results or interpretation of their data.

Table 1. Search strategy in the different databases used

Database	Search term
PubMed	("Diet" OR "Food") AND ("Chronic Pain"[MeSH] OR "Musculoskeletal Pain") AND ("Rehabilitation"[MeSH] OR "Pain Management")
FSTA /Web of Science	TS=(("Diet" OR "Food") AND ("Chronic Musculoskeletal Pain" OR "Pain Management") AND "Rehabilitation")
ProQuest	("Diet" OR "Food") AND ("Chronic Musculoskeletal Pain" OR "Musculoskeletal Pain Management") AND ("Rehabilitation" OR "Functional Recovery")
Scopus	(TITLE-ABS-KEY("diet" OR "food") AND TITLE-ABS-KEY("chronic musculoskeletal pain" OR "pain management") AND TITLE-ABS-KEY("rehabilitation"))

Study selection

All studies identified by the search strategy were screened using the eligibility criteria that were previously specified. The first stage of assessment involved the screening of titles and abstracts. The same reviewer undertook the second stage, screening the full text.

Data extraction

Extracted the following relevant data from each study: study details (first author, year of publication), characteristics of participants, setting, pain condition, outcome measures, based on ICF model, duration of follow-up, and study design.

Assessment of the methodological quality of RCTs

The methodological quality of the RCTs was assessed using the Cochrane risk of bias scale. The Cochrane Risk of Bias Tool is a systematic method for evaluating the quality and reliability of research studies, particularly focusing on the assessment of both external and internal validity. It utilizes a seven-item scale to scrutinize various aspects of a study, with each item (except the first) contributing one point upon completion. This scoring mechanism allows for a total score ranging from 0 to 7 points, providing a quantifiable measure of the potential risk of bias within the study (12).

Meta-analysis

To ascertain the overall impact of dietary interventions on pain outcomes, a Meta-analysis was conducted wherever feasible. The following data were collected: reported sample size, mean values, and standard deviations of pain outcome measurements. Studies utilizing the Visual analog scale (VAS) for pain outcomes were included in the Meta-analysis, with all VAS data converted to a 0-100 scale when necessary. In the absence of significant heterogeneity, a fixed-effects model was applied. The Meta-analysis was performed using Stata version 17.0 (Stata Corp LLC, Texas, USA).

Results

The results found in the different selected studies are detailed below.

Study selection

The searches performed in the seven different databases yielded: PubMed, FSTA Web of Science, ProQuest, and Scopus. All those that did not meet the aforementioned inclusion criteria were eliminated. Finally, a total of 7 studies were yielded that met the predefined criteria and were selected, including 7 RCTs. The study selection process is shown in Figure 1.

Assessment of methodological quality

A methodological quality assessment was carried out using the different scales with the results being shown in Table 2. The development of the general characteristics of the selected studies is shown in Table 3.

Study instruments

Physical function: pain

The results demonstrate that, when using the Visual Analogue Scale to measure the outcome of dietary treatment in relation to pain, three out of four studies showed significant differences between groups, whereas the other study showed that neither group improved. One study assessed the Brief Pain Inventory (BPI) and found that both groups improved significantly. The study by Du et al., 2019, showed no significant change in Western Ontario and McMaster University Osteoarthritis Index (WOMAC) pain subscores. Conversely, the studies conducted by Torlak

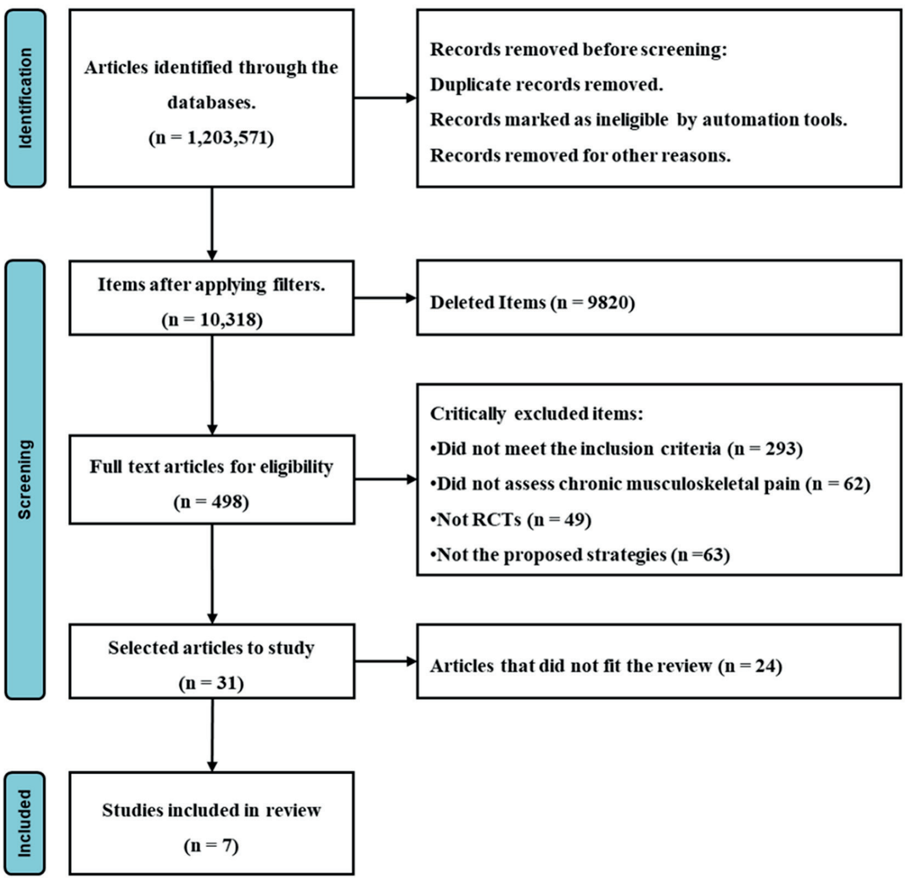

Figure 1. Flow diagram according to the PRISMA system. Study selection and exclusion process.

Table 2. Study of the methodological quality of the RCTs through the Cochrane Risk of Bias Scale

Cochrane risk of bias		Selection bias		Performance bias	Detection bias	Attrition bias	Reports bias	Other bias	Total
Number	Article (AMA format with first author and year)	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selection reporting	Anything else, ideally prespecified	Total score
1	Lozano-Plata et al., 2021	Yes	Yes	No	No	Yes	Yes	Yes	5/7
2	Guagnano et al., 2021	Yes	Yes	No	Yes	Yes	Yes	Yes	6/7
3	Messier et al., 2013	Yes	Yes	Yes	No	Yes	Yes	Yes	6/7
4	Torlak et al., 2022	Yes	Yes	Yes	No	Yes	Yes	Yes	6/7
5	Field et al., 2022	Yes	Yes	Yes	No	Yes	No	Yes	5/7
6	Vadell et al., 2020	Yes	Yes	Yes	No	Yes	Yes	Yes	6/7
7	Du et al., 2019	Yes	Yes	Yes	No	Yes	Yes	Yes	6/7

Yes = fulfills the requirements for no bias, No = does not fulfill the requirement for no bias.

et al., 2022, indicate that specific combinations of diet and physical interventions can substantially reduce pain. The results are shown in Table 4 (13-19).

Physical function: Inflammation

There is insufficient evidence to demonstrate that diet modification and food choices can reduce inflammation. Various studies have examined the levels of Erythrocyte Sedimentation Rate (ESR) and interleukins, which are components of inflammation. In the study by Guagnano et al., no significant change in ESR was observed, reflecting the unchanging nature of inflammation in response to the tested interventions ($p = 0.885$). Conversely, research by Messi et al. and Torlak et al. highlighted a substantial decrease in inflammation markers, IL-6, and ESR respectively, when dietary measures were combined with physical activity ($p = 0.008$ and $p < 0.001$, respectively). However, studies by Field R et al. and Du C et al. presented contradictory results, with no significant changes in inflammatory factors ($p = 0.194$ and $p > 0.001$, respectively). The results are shown in Table 5 (13-19).

Quality of life: activities and participation

In evaluating the impact of diet and rehabilitation interventions on quality of life among individuals with chronic musculoskeletal pain, recent studies present a diverse array of findings. Lozano-Plata et al. 2021 utilized the FM Impact Questionnaire and observed no significant difference in outcomes between the experimental and control groups post-intervention. Conversely, Guagnano et al. 2021, Messi et al. 2013, and Torlak et al. 2022 each reported significant improvements in quality of life as measured by the SF-36 Short Form Health Survey and the Barthel Index (BI), respectively, with the interventions including diet, exercise, or a combination of both. These studies highlighted the efficacy of integrated approaches, indicating a P value of less than 0.001, suggestive of strong positive effects. In a similar vein, Du et al. 2019 found a significant improvement in the experimental group compared to the control group using the WOMAC, with a P value of less than 0.05, underscoring the potential benefits of such interventions. However, the study by Field et al. 2022, despite employing the SF-12 Short Form Health Survey, did not demonstrate a

Table 3. Development of the general characteristics of the selected studies

First Author, Date, Design of the study	Disease	Description of Participants	Description of painkillers	Intervention Conditions	Control conditions	Outcome measures
Lozano-Plata LI et al., 2021, RCT (13)	FM	**Key inclusion criteria:** 1. Female > 18 years old 2. Met ACR criteria for FM. **Key exclusion criteria:** 1. Previous vitamin D use 2. Known with kidney diseases, hepatic diseases, calcium metabolism disorders, mal-absorption disorders, known neoplasm 3. Serum calcium levels equal to or greater than 10.2 mg/dL **Baseline Characteristic:** N = 80, female, 1 withdrew. Vitamin D (n=40), Age: 50.3(11.9) years old; BMI: 26.8(7.3) kg/m^2. Placebo (n=40), Age: 51.4(9.5) years old; BMI: 27.2(5.29) kg/m^2.	Not mentioned	n= 39 50,000 IU of Vitamin D3, weekly for 12 weeks + standard treatment for pain management	n= 40 Matching placebo, weekly for 12 weeks + standard treatment for pain management	1. Clinical chemistry tests including 25 OH Vitamin D levels, Serum calcium levels. 2. Fibromyalgia Impact Questionnaire (FIQ) (score from 0 to 100, 100 is the highest score) 3. VAS (score from 0 to 10, 10 is the highest score) 4. Mini Neuropsychiatric Interview
Guagnano et al., 2021, RCT (14)	RA	**Key inclusion criteria:** 1. Female, age 31-72 years old 2. Treated with the same optimized therapy for at least one year (biological and conventional Disease-Modifying Antirheumatic drugs (DMARD), or monotherapy with a biological drug, or conventional only DMARDs) 3. Stable disease activities **Key exclusion criteria:** 1. Comorbidities (diabetes, dyslipidemia, celiac disease) 2. Treatment with medium to high doses of corticosteroids (above 7.5 mg/day or prednisone equivalent) 3. Dietary regimens with avoidance of meat, gluten, or milk **Baseline Characteristic:** N = 40, female, 12 withdrew Group A(follow a diet excluding meat, gluten and lactose) (n=20), Age: 50.6 ± 2.24 years; BMI: 29(26-36) kg/m^2. Group B(follow a balanced diet) (n=20) Age: 50.60 ± 2.24 years; BMI: 29 (25-33.5) kg/m^2.	Participants were allowed to be used during the study: low-dose steroid therapy (less than 7.5 mg Prednisone equivalent/ day) and occasional use of Nonsteroidal Anti-inflammatory Drugs or analgesics were allowed throughout the study.	n = 15 A diet excluding meat, gluten, and lactose (1500 kcal/ day) + optimized according to current guidelines for balanced composition in macronutrients, daily intake of cholesterol (<300 mg/die) saturated fatty acids (<10% of total energy intake) oligosaccharides (<15% of total energy intake), and dietary fiber (25–30 g/die) Total protein intake was 50% from animal and 50% from vegetable proteins	n = 13 A balanced diet + optimized according to current guidelines for balanced composition in macronutrients, daily intake of cholesterol (<300 mg/die) saturated fatty acids (<10% of total energy intake) oligosaccharides (<15% of Total energy intake), and dietary fiber (25–30 g/die) Total protein intake was 50% from animal and 50% from vegetable proteins	1. Disease Activity Score-28 joints (DAS-28) 2. VAS 3. Short Form Health Survey (SF-36) – how the disease condition affected their quality of life 4. Health Assessment Questionnaire 5. Clinical chemistry tests including Oral Glucose Tolerance Test, Homeostasis Model Assessment index, insulin level, serum lipid profile, ESR, high-sensitivity C-reactive protein, transaminase levels, total proteins, albumin, and transferrin

Messi et al., 2013, RCT (15)	Knee OA	**Key inclusion criteria:** 1. Ambulatory, community-dwelling person, age >55 years old 2. Kellgren-Lawrence14 grade 2 or 3 (mild or moderate) radiographic tibiofemoral OA or tibiofemoral plus patellofemoral OA of one or both knees 3. Pain on most days due to knee 4. BMI 27-41 kg/m^2 5. Sedentary lifestyle (< 30 minutes per week of formal exercise for the past 6 months) **Key exclusion criteria:** 1. BMI < 27 or > 41 kg/m^2 2. Knee or hip replaced history 3. Moderate physical activity 4. Age < 55 years old 5. Comorbidities include heart condition, cancer **Baseline Characteristic:** N = 454 Exercise group (comparison) (n=150), Age: 66(6) years old; Female: 108(72); BMI: 33.5 (3.7) kg/m^2. Diet group (n=152), Age: 66(6) years old; Female: 108(71); BMI: 33.7(3.8) kg/m^2. Diet + Exercise group (n=152), Age: 65(6) years old; Female: 109(72); BMI: 33.6(3.7) kg/m^2.	Not mentioned	Diet (D) + Exercise (E) Group (N = 136) Combined Intervention: Participants received both the dietary and exercise interventions as outlined for the D and E groups, targeting both diet control and regular physical activity.	D Group: (n = 134) Aimed for 10-15% weight loss from baseline with a diet consisting of partial meal replacements and a controlled third meal. Caloric intake was tailored to individual weight change, with a nutritional balance according to recommended dietary intakes. E Group: (n = 129) Engaged in 1 hour of exercise three times a week for 18 months, initially center-based and later with the option for home-based activities. The routine included walking, strength training, and additional aerobic exercises.	1. Fat mass, mean, kg 2. Lean mass, mean, kg 3. 36-item short form (SF-36) 4. WOMAC 5. Knee compress force 6. IL-6 levels
Torlak et al., 2022, RCT (16)	Chronic LBP	**Key inclusion criteria:** 1. Chronic LBP, age 40-65 years old 2. Tested positive for the VAS > 5/10 3. BMI > 25 kg/m^2 **Key exclusion criteria:** 1. Engaged in active exercise 2. Regularly take painkillers or anti-depressants and cortisone 3. Pregnant 4. Severe chronic illness and spine surgery **Baseline Characteristic:** N = 60 Diet group (n=20), Age: 50.3±1.64 years old; Female: 10(50); BMI: 33.23±1.32 kg/m^2. Diet + Physical Therapy group (n=20), Age: 54.3±1.38 years old; Female: 10(50); BMI: 32.91±0.80 kg/m^2. Physical Therapy group (n=20), Age: 54.85±3.81 years old; Female: 10(50); BMI: 30.2±1.05 kg/m^2.	Individuals who regularly take painkillers or anti-depressant and cortisone were excluded from the study.	Combined Group (Diet + Physical Therapy, Group D+PT-G) (n=20) This group participated in both the dietary program as the DG and the physical therapy regimen as the PTG for the same 5-week period.	(Physical Therapy Group-PTG) (n=20) These patients underwent physical therapy five times a week for five weeks, including a 20-minute hot pack, transcutaneous electrical nerve stimulation (TENS) for 20 minutes, and ultrasound therapy for an average local exposure of 8 minutes per session. (Diet Group-DG) (n=20) Participants followed a strict diet for two days a week, consisting of high-protein foods, low-fat dairy, certain vegetables or fruits, low-calorie liquids, and multivitamins, totaling about 600-700 kcal. For the other five days, they adhered to a Mediterranean diet with a higher caloric intake. This was monitored daily through interviews and weekly diet registrations over 5 weeks, with the first week as an adaptation period.	1. Body Weight 2. Height 3. BMI (kg/m^2). 4. VAS 5. Leeds Assessment of Neuropathic Symptoms and Signs (LANSS): determine whether a patient's pain has a neuropathic component, s0-24, 24 highest 6. BI: A scale to measure performance in activities of daily living, assessing the ability of an individual to function independently. It is scored from 0 (totally dependent) to 100 (fully independent).

Table 3 (*Continued*)

First Author, Date, Design of the study	Disease	Description of Participants	Description of painkillers	Intervention Conditions	Control conditions	Outcome measures
Field et al., 2022, RCT (17)	Chronic musculoskeletal pain	**Key inclusion criteria:** 1. Age > 18 years old 2. Pain > 3 months 3. Eating standard western diet **Key exclusion criteria:** 1. Taking insulin or oral hypoglycemic medications 2. Had a history of eating disorders 3. Bariatric surgery 4. Recent weight loss **Baseline Characteristic:** N = 24 Whole-food diet group (n=9), Age: 50±12 years old; Male/Female: 1/8; BMI: 28.9±6.6 kg/m^2. Whole food/well-formulated ketogenic diet (n=15), Age: 54±15 years old; Male/Female: 3/12; BMI: 28.4±4.6 kg/m^2.	Participants were required to maintain their prescribed pain medication but record any changes in optional pain medication use.	n = 14 Whole food diet (3 weeks) + well formulated ketogenic diet (9 weeks): with a reduction in carbohydrate intake to between 30 and 50 g/day to achieve nutritional ketosis with a ketone level of 0.5–3.0mmol/L	n = 8 Whole food diet (12 weeks)	1. BPI: ates pain severity (worst, lowest, average, and current VAS) and pain interference (general activity, mood, walking ability, normal work, relationships with others, sleep, and enjoyment of life VAS) in the previous 24 hours 2. daily online diary (REDCap) rating the worst, least, and average pain VAS for the day 3. finger-prick testing for ketones and blood glucose 4. laboratory blood biomarkers 5. ASA24 6. SF-12 for quality of life
Vadell et al., 2020, RCT (18)	RA	**Key inclusion criteria:** Disease Activity Score in 28 joints-Erythrocyte Sedimentation Rate (DAS28-ESR) ≥2.6 (rounded to 1 decimal place) at screening and clinically stable disease under adequate control, i.e., no changes in immunosuppressive treatment (DMARDs) during the preceding 8 weeks. **Key exclusion criteria:** Allergies or intolerances to food included in the study, inability to understand the information, other serious illnesses, pregnancy, and lactation. **Baseline Characteristic:** N = 50 Age: 61±12 years old; Female: 36(77); BMI: 27.6±5.4 kg/m^2.	Not mentioned	n= 26 A portfolio diet based on several food items with suggested anti-inflammatory effects during 2 × 10 weeks with 3 months wash-out between diets.	N =24 A control diet during 2 × 10 weeks with 3 months wash-out between diets.	DAS-28 a composite score which predicts disability and progression of RA

Du et al., 2019, RCT (19)	Knee OA	**Key inclusion criteria:** 1. age =. 45-79 years old 2. knee OA **Key exclusion criteria:** 1. Smoke more than 1 pack per day 2. Uncontrolled diabetes 3. Heart failure, history of knee replacement 4. Using prescribed COX-2 inhibitors 5. allergic to blueberries **Baseline Characteristic:** N = 63 Blueberry (n=33), Age: 57.2±1.8 years old; Male/Female: 9/24; BMI: 32.1±1.3 kg/m^2. Placebo (n=30), Age: 55.3±1.5 years old; Male/Female: 7/23; BMI: 30.2±1.4 kg/m^2.	Those who were using prescribed COX-2 inhibitors were excluded.	n = 33 40 g of freeze-dried whole blueberry powder daily, 4 months	n =30 Consume 40 g of control powder daily, 4 months	1. WOMAC 2. Gait and balance were analyzed using a GAITRite® system 3. Biomarker: 4. IL-1β, IL-6, TNF-α, IL-10, IL-13, MMP-3, MMP-13, and MCP-1

Pain Scale VAS (Visual Analog Scale): Used to measure pain intensity, the VAS reflects the 'Body Functions' component in the ICF model, allowing patients to rate their pain on a scale typically from 0 to 10 (20).
Brief Pain Inventory (BPI): In the context of chronic pain and dietary interventions, the BPI effectively measures pain severity and its impact on functionality and quality of life. This tool aligns with the 'Body Functions' and 'Activities and Participation' components in the ICF model, through its assessment of pain's physical and functional implications (21).
Fibromyalgia Impact Questionnaire (FIQ): Designed specifically for FM, this questionnaire evaluates the condition's impact on physical and psychological aspects, encompassing 'Body Functions' and 'Activities and Participation' in the ICF model (22).
SF-36 Short Form Health Survey: The SF-36 is a comprehensive health status measure, assessing physical and mental health across eight dimensions, reflecting 'Body Functions', 'Body Structures', and 'Activities and Participation' in the ICF (23).
SF-12 Short Form Health Survey: A condensed version of SF-36, the SF-12 focuses on overall health and well-being, covering multiple ICF components and providing a broad overview of health status (24).
Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC): Targeting OA, the WOMAC evaluates pain, stiffness, and physical function, primarily reflecting 'Body Functions' and 'Activities and Participation' in the ICF related to OA (25).
Barthel Index (BI Index): The Barthel Index assesses the ability of individuals with physical impairments to perform daily activities, indicating independence level, and directly relates to 'Activities and Participation' in the ICF (26).
DAS-28 (Disease Activity Score-28 for Rheumatoid Arthritis): DAS-28 is a composite score assessing rheumatoid arthritis activity, based on joint counts and inflammatory markers, reflecting 'Body Functions' in the ICF with a focus on joint and inflammatory activity (27).

Table 4. Physical function: pain

Citation	Measurement outcome	EXP = results	CTL = results	Between group effect size
Lozano-Plata et al., 2021	VAS	N = 39 Pre-test: 6.00 ± 3.00 Post-test: 4.90 ± 0.90	N = 40 Pretest: 6.00 ± 3.50 Posttest: 5.19 ± 0.83	P value = 0.705
Guagnano et al., 2021	VAS	N = 15	N = 13	P value = 0.003
Messi et al., 2013	VAS	N =136 Diet (D) + Exercise (E) 3.6 (3.20 to 4.10)	N =134 Exercise (E) 4.7 (4.20 to 5.10) N = 129 Diet (D) 4.8 (4.30 to 5.20)	P value < 0.001
Torlak et al., 2022	VAS	N = 20 Diet (D) + physical therapy (PT) Pretest: 7.45 ±0.44 Posttest: 4.70 ± 0.42	N = 20 Physical therapy (PT) 4.7 (4.20 to 5.10) Pretest: 6.65 ±0.31 Posttest: 3.10 ± 0.38 N = 20 Diet (D) Pretest: 4.80 ±0.88 Posttest: 2.30 ± 0.59	P value < 0.001
Torlak et al., 2022	LANSS	N = 20 Diet (D) + physical therapy (PT) Pretest: 10.60 ± 0.88 Posttest: 7.10 ± 0.76	N = 20 Physical therapy (PT) 4.7 (4.20 to 5.10) Pretest: 5.10 ±0.43 Posttest: 2.60 ± 0.36	P value < 0.001
Field et al., 2022	BPI	N = 14 Pretest: 44.00 ± 15.00 Posttest: -17.9 ± 5.20	N = 8 Pretest: 64.00 ± 13.00 Posttest: 4.90 ± 0.90	P value < 0.001
Du et al., 2019	WOMAC sub-group pain	N = 33	N = 30	P value > 0.001

significant difference between the experimental and control groups, indicating a P value of 0.888. These findings collectively suggest that while certain interventions can lead to significant enhancements in quality of life for those suffering from chronic musculoskeletal pain, the variability in outcomes across different measures and studies points to the need for further nuanced research to elucidate the specific elements that contribute most effectively to improving outcomes. The results are shown in Table 6 (13-19).

Effect of diet intervention on pain

Meta-analysis of fixed-effect model showed that the participants who participated in dietary intervention had lower VAS score than those who did not (P<0.001), and the effect value was -4.33 (95% CI:-6.01-2.64) (Figure 2).

Discussion

The objective of this study was to systematically review the existing scientific evidence on the efficacy of dietary modification and food choice applied to improve body function, physical activities, and social participation in chronic musculoskeletal pain and health. Seven studies that met pre-defined criteria were included. While most published systematic review studies have examined the effects of diet and food choices

Table 5. Physical function: Inflammation

Citation	Measurement outcome	EXP = results	CTL = results	Between group effect size
Guagnano et al., 2021	ESR	N = 15 Pretest: 21.00 ± 4.00 Posttest: 21.9 ± 3.00	N = 13 Pretest: 16.00 ± 3.00 Posttest: 22.0 ± 3.10	P value = 0.885
Messi et al., 2013	IL-6,pg/mL	N =136 Diet (D) + Exercise (E) Pretest: 3.00 (2.60 to 3.30) Posttest: 3.00 (2.70 to 3.31)	N =134 Exercise (E) Pretest: 3.10 (4.20 to 5.10) Posttest: 2.70 (2.30 to 3.0) N = 129 Diet (D) 4.8 (4.30 to 5.20)	P value = 0.008
Torlak et al., 2022	ESR	N = 20 Diet (D) + physical therapy (PT) Pretest: 2.66 ± 2.75 Posttest: 2.34 ± 2.54	N = 20 Physical therapy (PT) 4.7 (4.20 to 5.10) Pretest: 1.99 ± 2.08 Posttest: 2.32± 2.32	P value < 0.001
Field et al., 2022	ESR	N = 14	N = 8	P value = 0.194
Du et al., 2019	ESR, IL-10, IL-13	N = 33	N = 30	P value > 0.001

Table 6. Quality of life: physical activities and participation

Citation	Measurement outcome	EXP = results	CTL = results	Between group effect size
Lozano-Plata et al., 2021	FIQ	N = 39 Pretest: 64.51± 15.25 Posttest: 46.28 ± 17.18	N = 40 Pretest: 61.88 ± 18.21 Posttest: 44.54 ± 6.08	P value = 0.732
Guagnano et al., 2021	SF-36 Short Form Health Survey	N = 15	N = 13	P value < 0.001
Messi et al., 2013	SF-36 Short Form Health Survey - physical	N =136 Diet (D) + Exercise (E)	N =134 Exercise (E) N = 129 Diet (D)	P value < 0.001
Torlak et al., 2022	BI	N = 20 Diet (D) + physical therapy (PT) Pretest: 98.10 ± 1.28 Posttest: 99.50 ± 0.50	N = 20 Physical therapy (PT) 4.7 (4.20 to 5.10) Pretest: 90.00 ± 2.25 Posttest: 94.80 ± 0.50 N = 20 Diet (D)	P value < 0.001
Field et al., 2022	SF-12 Short Form Health Survey	N = 14 Pretest: 64.00 ± 15.00 Posttest: 65.00 ± 13.00	N = 8 Pretest: 62.00 ± 13.00 Posttest: 68.00 ± 14.00	P value =0.888
Du et al., 2019	WOMAC total	N = 33	N = 30	P value <0.05

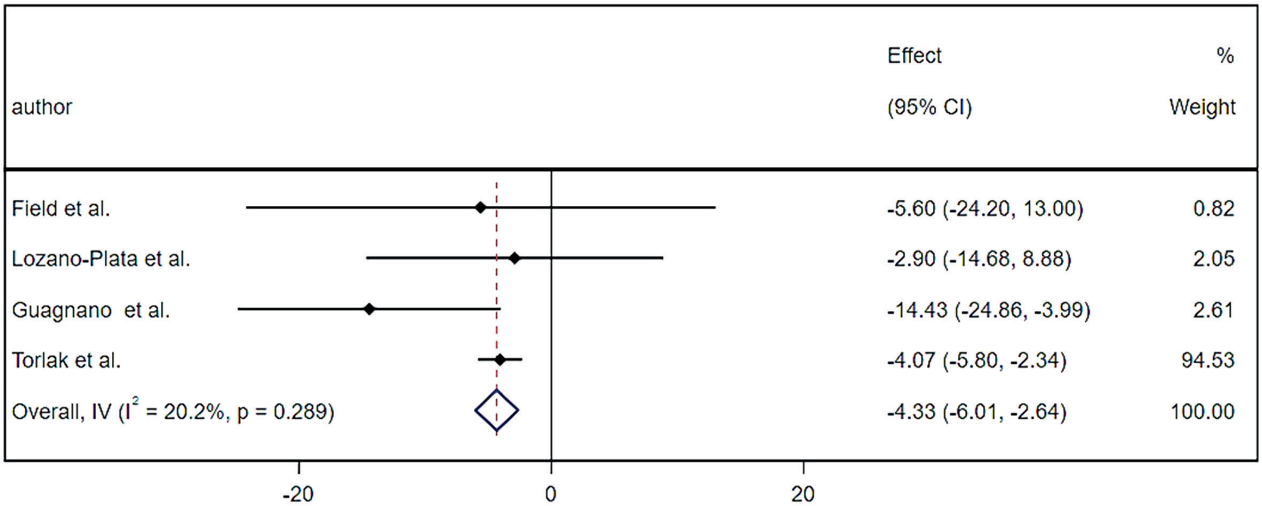

Figure 2. Effect of diet intervention on pain.

on general chronic pain, the current study focused on the impact of diet on generalized chronic musculoskeletal pain. Based on this review, there are various mechanisms through which specific diets may reduce chronic musculoskeletal pain. For instance, a low-carbohydrate ketogenic diet can modulate carbohydrate metabolism, aligning metabolism and leading to the oxidation of fatty acids and the production of ketone bodies for energy. This results in potential therapeutic outcomes, including the reduction of neuroinflammation and desensitization. Similarly, diets that exclude meat, gluten, and lactose may decrease systemic inflammation. Additionally, combining therapeutic exercises can enhance the vascular changes associated with diet and the influence of exercise, helping to moderate pain and improve physical outcomes. Meanwhile, anti-inflammatory diets have a positive impact on inflammatory factors and enhance antioxidant outcomes (13-19). Of the selected seven studies, six showed an improvement in chronic musculoskeletal pain in different domains related to the ICF model in response to different diet modifications and food choices. The "Vitamin D3 in Fibromyalgia" study explored the impact of weekly Vitamin D3 supplementation on FM patients. In the "Exclusion Diet in Rheumatoid Arthritis," researchers focused on an exclusion diet aimed at reducing inflammation and pain in RA patients. The "Diet and Exercise in Knee Osteoarthritis" study evaluated the effects of intensive diet and exercise on knee joint loads, inflammation, and clinical outcomes in overweight and obese adults with knee OA. Additionally, the "Intermittent Diet and Physical Therapy in Chronic LBP" research combined intermittent dieting with physical therapy to alleviate chronic LBP. The "Low-Carbohydrate Ketogenic Diet in Chronic Pain" study investigated the effects of a low-carbohydrate ketogenic diet on reported pain, blood biomarkers, and quality of life in chronic pain patients. This 12-week intervention began with 3 weeks of eliminating ultra-processed foods, followed by randomization to either a whole-food/well-formulated ketogenic diet or a minimally processed whole-food diet. Furthermore, the "Anti-Inflammatory Diet in Rheumatoid Arthritis (ADIRA)" trial aimed to determine if an anti-inflammatory diet, consisting mainly of fish, legumes, whole grains, vegetables, fruits, low-fat dairy, and probiotics, could reduce disease activity in patients with RA. Lastly, the "Blueberries in Knee OA" study tested the effect of freeze-dried whole blueberries on pain, gait performance, and inflammation in individuals with symptomatic knee OA. Each study represents a unique approach to dietary intervention, illustrating the diverse and targeted strategies employed in the field of food studies and rehabilitation medicine (13-19).

Strengths and weakness of the study

This review presents several strengths. First, it employs various scales to enable a comprehensive methodological assessment of the quality of the included studies and their results. Second, the study focused solely on studies designed as RCTs, considered the gold standard in research of this kind. Finally, the study highlights current gaps in our understanding of how food studies and rehabilitation can be combined to impact individuals suffering from chronic musculoskeletal pain and proposes new directions for future research. On the other hand, some weaknesses are noted. Seven studies identified for inclusion in the review were not that large a number. There should be a need of more RCTs in the diet and rehab field for chronic musculoskeletal pain. The extensive range of food choices and diets complicates the extrapolation of results to specific categories. Moreover, due to the heterogeneity of the participants, the results of this study should be interpreted with caution. Finally, the study did not isolate specific diets to compare their effectiveness against other treatment options.

Clinical application, future research lines

Current scientific studies show that the majority of chronic musculoskeletal pain cases are chronic LBP, FM, and arthritic joint diseases (28). The application of different dietary strategies combined with various medical treatments may be effective. This is because there is a gap between food and nutritional studies and rehabilitation medicine studies, due to differences in the scope of practice. Each of these studies has focused on its own field with a lack of cooperation. Combining these with other treatment methods can better elucidate the physiological aspects of chronic musculoskeletal pain across multiple domains. Additionally, the lack of consideration of the quality of the social domain and the psychosocial domain might be a drawback in current studies, due to still mixed evidence on baseline outcome measurements of pain and other functional scales, or limited resources. Future studies should address both the correlation and more comprehensive outcomes. Treatment of patients with chronic musculoskeletal pain requires a holistic approach, considering the impact of rehabilitation and exercise on the individual as a whole and taking into account the fact that diet can significantly affect the progression of rehabilitation. For clinical practitioners, considering diet and food modifications can create an impact on clinical outcomes and improve quality of life. There is a need for food studies researchers to team up with rehabilitation researchers to design treatment trials that address the current gaps in chronic pain management. Research in chronic musculoskeletal pain can benefit from a focus on understanding the impact of diet. This area of nutrition rehabilitation needs to receive more attention from both nutrition and rehabilitation researchers.

Conclusion

Overall, there is mixed evidence regarding the association of diet modification and food choices with inflammation and positive impact on pain and quality of life. The dietary modifications and food choices examined in studies about chronic musculoskeletal conditions showed similar or better improvements in these areas. These dietary modifications and food choices include anti-inflammatory diets primarily composed of fish, vegetarian dishes, fruits (especially blueberries), low-fat dairy rich in vitamin D, a low-carbohydrate ketogenic diet, and exclusion diets that eliminate meat, gluten, and lactose. The effects of various food strategies on pain and inflammation, particularly when combined with exercise or rehabilitation, are promising both in the short and long term. These results highlight the need to integrate biological, psychological, and social dimensions to improve effective pain management strategies. The outcomes promote a more integrative approach to food studies and rehabilitation, consistent with the biopsychosocial paradigm of the ICF model.

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