ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2025/330–342/$2.00/©JCCA 2025

The pathophysiologic mechanisms of spinal manipulative therapy in the management of chronic musculoskeletal pain

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Chronic musculoskeletal (MSK) pain is a leading cause of disability affecting patients and healthcare systems worldwide. Its burden is expected to rise sharply due to the aging global population. Given that chronic MSK pain is the most common condition treated by chiropractors daily, chiropractic is ideally positioned to assume a unique leadership role in the future health delivery system of managing this growing clinical challenge. Central sensitization (CS) is linked to an increasing number of chronic pain conditions characterized by increased sensory, sympathetic, and motor excitability. Accumulating evidence suggests that spinal manipulation may achieve its therapeutic

Les mécanismes pathophysiologiques de la thérapie manuelle vertébrale dans la gestion de la douleur musculosquelettique chronique.

La douleur musculosquelettique chronique est une cause importante d'incapacité touchant les patients et les systèmes de santé dans le monde entier. On s'attend à ce que son fardeau augmente considérablement en raison du vieillissement de la population mondiale. Étant donné que la douleur musculosquelettique chronique est le problème de santé le plus courant traité par les chiropraticiens quotidiennement, la chiropratique est dans la position idéale pour assumer un rôle de leadership unique dans le futur système de prestation de soins de santé visant à gérer ce défi clinique croissant. La sensibilisation centrale (SC) est en lien avec un nombre croissant de problèmes de douleur chronique caractérisés par une excitabilité sensorielle, sympathique et motrice accrue. Les données probantes accumulées suggèrent que la manipulation vertébrale pourrait obtenir des bienfaits thérapeutiques en modulant la SC, ce qui en fait une approche potentiellement efficace et non invasive pour traiter

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Conflicts of Interest:
This research was funded by the OCA. The authors declare no other conflicts of interest, including no disclaimers, competing interests, or other sources of support or funding to report in the preparation of this manuscript.

benefits by modulating CS, thereby making it a potentially effective non-invasive approach to treating and managing chronic MSK pain. This review aims to provide a discussion of some of the scientific foundations underpinning the pathophysiologic mechanisms of chronic MSK pain and spinal manipulative therapy, as they relate to the contemporary neurophysiologic paradigm of chiropractic medicine and practice.

Author's Note: This paper is one of seven in a series exploring contemporary perspectives on the application of the evidence-based framework in chiropractic care. The Evidence Based Chiropractic Care (EBCC) initiative aims to support chiropractors in their delivery of optimal patient-centred care. We encourage readers to review all papers in the series.

(JCCA. 2025;69(3):330-342)

KEY WORDS: chiropractic, chronic musculoskeletal pain, central sensitization, spinal manipulative therapy

et gérer la douleur musculosquelettique chronique. Cette revue vise à offrir une discussion sur certains des fondements scientifiques sous-jacents aux mécanismes pathophysiologiques de la douleur musculosquelettique chronique et de la thérapie manuelle vertébrale, en relation avec le paradigme neurophysiologique contemporain de la médecine et de la pratique chiropratiques.

Note de l'auteur: Ce document fait partie d'une série de sept documents examinant les perspectives contemporaines sur la mise en œuvre du cadre fondé sur des données probantes pour les soins chiropratiques. L'initiative de soins chiropratiques fondés sur des données probantes (SCFDP) vise à soutenir les chiropraticiens dans la prestation de soins optimaux axés sur le patient. Nous encourageons les lecteurs à consulter tous les articles de la série.

(JCCA. 2025;69(3):330-342)

MOTS CLÉS : chiropratique, douleur musculosquelettique chronique, sensibilisation centrale, thérapie manuelle vertébrale

Introduction

Chronic musculoskeletal (MSK) pain, such as low back and neck pain, is a leading cause of disability affecting both patients and health delivery systems worldwide.[1,2] The International Association for the Study of Pain temporally defines chronic pain as pain persisting for longer than three months.[3] One in five Canadian adults live with chronic pain, 50% of which have lived with the condition for over ten years.[4] Those numbers are expected to rise worldwide due to the aging global demographic, placing significant economic burden on healthcare systems.[1,2,4] A recent Health Canada report revealed the total cost of chronic pain conditions, which includes both direct (healthcare) costs and indirect (lost production) costs, was between $38.2 and $40.3 billion in 2019 alone.[4] The growing burden of chronic MSK pain necessitates the advancement of effective and cost-efficient treatment strategies to help manage and mitigate the economic burden on healthcare systems.[1,4,5]

Despite its prevalence, the underlying mechanisms driving chronic MSK pain are still poorly understood. A growing body of research highlights the important role of central sensitization (CS) as a key underlying mechanism driving the pathophysiology and clinical manifestation of chronic MSK pain syndromes that are commonly managed by chiropractors, including chronic low back pain and osteoarthritis.[6–8] To this extent, understanding the physiological mechanisms of CS is relevant to chiropractors as it applies to the diagnosis and management of chronic MSK pain syndromes.[6]

Spinal manipulative therapy (SMT) is a cost-effective manual therapy technique utilized by chiropractors and a variety of healthcare practitioners.[9,10] Substantial evidence supports the use of SMT for the treatment of MSK disorders[11] and is recommended in guidelines for the treatment of chronic neck[12] and low back pain[13], two of the most prevalent conditions leading to disability[2]. Despite its widespread use, the underlying biological mech-

anisms mediating its therapeutic effects are still poorly understood. Previous literature suggests that SMT may achieve its therapeutic benefits via regional (segmental, heterosegmental) modulation of CS, making it an effective option in the ongoing management of chronic MSK pain.[5,14–16]

This literature review aims to explore the emerging evidence describing the pathophysiology and clinical manifestation of chronic MSK pain, and the evidence supporting the mechanistic role of SMT in the management of chronic MSK pain.

Physiological mechanisms of central sensitization

CS begins as a normal, activity-dependent and reversible increase in the input-response profile (windup) of dorsal horn neurons (DHN) in response to nociceptive input.[17] However, under persistent nociception, this process can lead to a long-term maladaptive change in the neuron, called CS, resulting in phenotypic changes in both spinal and supraspinal centers.[6,17,18] Acute pain is driven by nociceptive input originating from primary pathologies residing within somatic or visceral tissues, releasing glutamate into the dorsal horn where it acts on AMPA (α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid) receptors to trigger excitatory post-synaptic potentials (EPSP).[19] CS, however, typically arises from persistent nociceptive bombardment which can lead to the activation of voltage-dependent calcium (Ca^{2+}) NMDA (*N*-methyl-D-aspartate receptor) channels, increased intracellular calcium and a cascade of downstream biochemical changes promoting the further neuronal excitability and sensitization.[18,19] Persistent nociception may further increase the release of gamma-aminobutyric acid (GABA).[20,21] Although generally inhibitory, activation of GABA-A receptors can depolarize dorsal root ganglia (DRG) cells under conditions of persistent nociception (Primary Afferent Depolarization), leading to enhanced excitability of interneuronal circuits.[20] If allowed to persist, this enhanced excitability can ultimately trigger a response known as the dorsal root reflex.[20,21] During this response, pro-inflammatory neuropeptides (substance P (sP), Calcitonin Gene-Related Peptide (CGRP)) are antidromically released into peripheral tissues; there, they trigger a neurogenically mediated inflammatory response (neurogenic inflammation) contributing to inflammatory pain and potentially a region of secondary hyperalgesia.[19–22]

The Neurogenic Hypothesis proposes that neurogenic inflammation is a foundational mechanism driving the pathophysiology and clinical manifestation of chronic inflammatory muscle pain (myofascial pain).[23] This hypothesis challenges the current prevailing consensus (Integrated Hypothesis) that acute local mechanical injury to the myotendinous unit necessarily precipitates the pathophysiology of myofascial pain.[24] Importantly, this hypothesis provides biological plausibility for viscerosomatic and somatovisceral comorbidities commonly observed clinically, but not reconcilable using the local injury paradigm. Examples of this include the comorbidity of myofascial pain with an increasing number of primary visceral disorders including chronic pelvic pain,[25] prostatitis,[26] and cystitis[27] in the absence of muscle injury. This shift in thinking challenges the idea that the myofascial trigger point is the primary pathology driving chronic myofascial pain but, in fact, represents a secondary physical manifestation of an existing primary pathology elsewhere within the neuromeric field of the affected muscle(s).

The neurogenic paradigm of myofascial pain suggests that persistent nociceptive signalling leading to CS can also activate preganglionic sympathetic neurons within the intermediate horn via synchronized neuronal firing, glial cell activation and neuroactive substances[28,29], such as substance P, glutamate and brain-derived neurotrophic factor (BDNF).[30,31] Brainstem areas including the paraventricular nucleus, rostral ventrolateral medulla, and periaqueductal gray also directly influence the intermediolateral (IML) nucleus via descending inputs. Enhanced sympathetic nervous system activity leads to hemodynamic changes and sympathetic hyperinnervation commonly observed in chronic myofascial pain syndrome.[32–34] Similar interneuronal mechanisms may also be responsible for changes in excitability of the motor unit pool within the ventral horn, also commonly observed with conditions of chronic MSK pain such as myofascial pain and osteoarthritis.[35–38]

Dysfunction in descending inhibitory pathways is also commonly observed in chronic pain patients.[39,40] Persistent nociceptive input influences key supraspinal centers related to descending inhibition of nociception and reduced perception of pain, including the periaqueductal grey and the rostroventral medulla.[41,42] Persistent nocicep-

tive barrage of the somatosensory cortex has also been shown to alter sensorimotor integration.[43] Psychological factors associated with chronic pain such as fear avoidance behaviours, kinesiophobia, and depression further alter descending antinociceptive activity of the periaqueductal grey matter (PAG).[44] These collective mechanisms contribute to the pain processing integrity of peripheral nociceptive and non-nociceptive somatosensory signals at both the level of the spinal cord and supraspinal structures that contribute to the clinical manifestation of persistent MSK pain.[41]

Clinical manifestation of central sensitization

CS is a neuroadaptive phenomenon characterized by an "amplification of neural signalling within the CNS"[6] leading to enhanced responsiveness of neurons to noxious stimulation (hyperalgesia) and non-noxious stimuli (allodynia), as well as expansion of pain responsiveness beyond the primary injury site into unaffected tissues (secondary hyperalgesia).[6–8,17,23,37] These dysesthesias are commonly reported in patients across a broad spectrum of chronic MSK pain syndromes including chronic low back pain, osteoarthritis, whiplash-associated disorder, fibromyalgia, headache and persistent painful tendinopathies.[6–8,45–47]

Given its complex and heterogeneous presentation, reliably identifying the clinical presence of CS can be challenging to the clinician. To this extent, several authors have attempted to establish mechanism-based classifications of CS.[48,49] For instance, in patients experiencing low back and leg pain, a strong indicator of CS may include a "disproportionate, non-mechanical, unpredictable pattern of pain provocation in response to multiple/non-specific aggravating/easing factors".[48] Patients with CS often present with positive findings of primary and/or secondary hyperalgesia on physical examination and often report pain that is inconsistent with the magnitude of tissue damage and/or persists beyond reasonable tissue healing times. Altered interactions between physical movement, mechanical stimuli and pain perception may further point to the possibility of maladaptive changes within the CNS.[48] Additionally, the presence of neuropsychiatric findings including sleep disturbance, anxiety, depression and brain fog are all highly suggestive of CS.[48]

Another key indicator of CS is the presence of enhanced Temporal Summation of Second Pain (TSSP), defined as increased pain perception to a train of repetitive stimuli of peripheral C-fibers delivered at a frequency greater than 0.33Hz.[50] TSSP is considered the psychophysical manifestation of windup, a frequency-dependent facilitation of neuronal excitability that shares common mechanisms with CS.[17,50] To this extent, enhanced TSSP and TSSP-M (maintenance) have been reported in fibromyalgia patients presenting with chronic widespread pain[51], suggesting it may be a clinically-feasible outcome measure in the assessment of chronic MSK patients.

Supraspinal effects of central sensitization

Numerous investigations have been conducted to examine the influence of CS on supraspinal function, which contributes to altered pain processing and heightened responsiveness to pain (hypersensitivity). Neuroimaging studies have revealed alterations in grey matter in the brain's pain processing areas in chronic pain patients, such as the thalamus, periaqueductal grey, insula, cingulate, and somatosensory cortex.[52] Increased levels of excitatory neurotransmitters (glutamate) and lower levels of inhibitory neurotransmitters (GABA) in the insula have also been observed following sensitization.[53] Alterations in neuroimmune function have been associated with conditions of widespread pain hypersensitivity, such as fibromyalgia [54], while altered brain network activity between pro- and anti-nociceptive pathways is an additional finding with significant implications to chronic pain.[55–57] As a result of these maladaptations, cortical inhibition of pain is diminished[58,59], and a wide range of pain-processing regions in the brain, including those involved in the emotional and cognitive aspects of pain, become more sensitive to nociceptive stimuli.[60,61]

These adaptations may have implications that go beyond pain perception, however. Prior studies have utilised transcranial magnetic stimulation (TMS) to examine the impact of experimentally induced CS on sensorimotor integration (SMI) and motor cortex excitability in healthy participants.[62–65] Somatosensory Evoked Potential (SEP) peaks associated with cerebellar inputs (N18), outputs (N24), and sensory processing were found to be substantially altered by experimentally induced CS[64], indicating that CS may elicit central processing adaptations within the brain. Collectively, these findings highlight how CS may not only amplify pain perception but also disrupt the brain's sensory, motor, and emotional processing, under-

scoring its potential broad impact on overall neurological function.

Clinical assessment of central sensitization

Significant progress has been made in the clinical assessment of CS. The Pain Sensitivity Questionnaire (PSQ)[66,67] and McGill Pain Questionnaire (MPQ)[68,69] are patient self-report questionnaires that allow clinicians to effectively assess the various dimensions of pain, such as sensory, affective, and evaluative aspects. These questionnaires provide reliable information on pain location, character, intensity, as well as emotional and cognitive dimensions. The Central Sensitization Inventory (CSI) is an additional self-report screening instrument utilised to identify individuals who may present with Central Sensitivity Syndrome (CSS)[70], a group of conditions that are linked to CS and heightened sensitivity to both somatic and visceral pain (e.g., irritable bowel syndrome, fibromyalgia). However, evidence suggests that while the PSQ correlates more closely with neurophysiological changes in nociceptive sensitization, the CSI is more strongly associated with psychological constructs[71] such as depression[72] and anxiety.[73,74] This distinction underscores the complementary roles of these tools in assessing different facets of CS. The robust psychometric properties of the validated CSI enable it to reliably distinguish chronic pain from neuropathic and nociceptive conditions and to identify patients exhibiting symptoms of CS, despite its primary correlation with psychological constructs.[75,76]

Advancements in clinically feasible diagnostic techniques hold promise in the quantitative assessment of the various physiological manifestations of CS. One area of particular interest is the clinical application of Quantitative Sensory Testing (QST) to systematically assess the integrity of the various modalities (pain, mechanical, temperature) of the somatosensory system.[17,77,78] The Pain Pressure Threshold (PPT) is a widely employed, clinically-feasible technique used to quantify the sensitivity to pressure in chronic MSK pain patients. The PPT is a static measure of the minimum pressure necessary to evoke pain (pain threshold). It is highly responsive to CS and chronic pain, showing significant decreases (i.e., increased sensitivity) in a variety of chronic MSK pain conditions associated with CS such as fibromyalgia,[79] osteoarthritis,[80] and non-specific low back pain.[81] Incorporating PPT into routine clinical assessment, however, requires specialized algometry equipment with careful training and experience to ensure consistency, reliability and accuracy.

A key limitation to PPT technique is that it does not provide insight into the temporal dynamics of pain processing in CS. The Windup Ratio (WUR) technique is a dynamic measure of the increase in pain perception in response to a train of repeating noxious stimuli. The WUR better reflects the underlying dynamics of temporal summation, the psychophysical expression of windup, which is enhanced under sensitized conditions.[82] Similar to PPT, WUR assessments require technical proficiency and specialized equipment for delivering controlled noxious stimuli.

Conditioned Pain Modulation (CPM) reflects the body's endogenous capacity to modulate pain perception. It is measured by testing a patient's response (excitatory or inhibitory) to noxious stimuli after the application of painful stimuli to a remote area of the body.[83,84] The neural circuitry involved in CPM includes brainstem regions such as the subnucleus reticularis dorsalis (SRD), as well as higher cortical areas such as anterior- and mid- cingulate cortices, dorsolateral prefrontal cortex. These cortical regions directly communicate with the periaqueductal gray which influences descending noradrenergic, serotonergic and dopaminergic pathways involved in pain modulation.[85] Impaired CPM is commonly observed in chronic pain conditions associated with CS including chronic low back pain[86] and osteoarthritis.[87] Inhibition of CPM is also a strong predictor for the development of chronic pain as well as response to treatment.[88,89] Moreover, while some studies find correlations between CPM and other measures of CS (e.g., CSI, PPT),[90] others report no significant relationship.[91] Further research is needed to elucidate this relationship and the role of CPM in the assessment of chronic pain.

Nociplastic pain is defined as pain arising from altered nociception in the absence of clear evidence of tissue injury or pathology.[92] CS is considered a key driver of nociplastic pain,[93] emphasizing the nervous system's role in mediating this type of pain. The nociplastic pain grading system, introduced by the International Association for the Study of Pain (IASP), provides a framework for evaluating pain phenotypes dominated by CS.[92] This grading system highlights key diagnostic features, includ-

ing widespread non-localized pain, somatosensory hypersensitivity (e.g., allodynia, hyperalgesia), and comorbidities such as sleep disturbance, anxiety and depression, fatigue and cognitive difficulty. [94–96] Nociplastic pain has been reported in several chronic pain conditions including fibromyalgia,[94] myofascial pain,[97] and chronic fatigue syndrome.[96] The phenotype of nociplastic pain is predominantly characterized by widespread, non-localized pain, both in the presence or absence of these affective co-morbidities.[93–97] While individual presentations may vary in intensity, comorbidities, and specific symptoms, this widespread pain pattern remains a defining feature. Despite this heterogeneity, adopting and integrating these criteria into clinical practice equips clinicians with tools for improved pain phenotyping and targeted mechanism-based management.

Spinal manipulative therapy in the management of central sensitization and musculoskeletal pain and dysfunction

SMT is a widely recognized manual therapy technique utilized by a variety of healthcare practitioners including chiropractors and physiotherapists for the treatment of MSK pain.[9,10] It is recommended for use in the treatment of acute and chronic non-specific low back pain, disc herniation with radiculopathy[13], as well as acute and chronic neck pain[12], which are amongst the top causes of disability worldwide.[2] SMT involves a high-velocity, low-amplitude thrust delivered to spinal zygapophyseal joints in areas of dysfunctional segmental motion identified through palpation and motion assessment.[98] Despite its many beneficial applications, the precise mechanisms by which SMT achieves its therapeutic benefits are still poorly understood.

Although the underlying mechanisms and their interrelationships remain unclear, the physiologic effects of SMT are largely attributed to biomechanical and/or neurophysiological mechanisms.[98] The proposed biomechanical effects of SMT include release of trapped meniscoids, release of abnormal adhesions connecting tissues, decreased intervertebral disc distortion, and restoration of 'buckled' segments; each of these serves to reduce mechanical stress on soft and hard tissues to enable intersegmental motion.[98,99] Additionally, it is speculated that the neurophysiological effects of SMT are intrinsically associated with the modulation of CS[100], however, no study to date has investigated the causal relationship between SMT and CS in a clinical population.[41,42] Emerging evidence also suggests that stimulation of large myelinated fibers via manipulation may induce synaptic depression, synaptic structural changes and even modifications in gene expression.[14], as discussed below.

Neurosegmental effects of spinal manipulation

The growing body of research suggests that SMT exerts its therapeutic benefit(s) by influencing neurosegmental activity at the dorsal, intermediolateral and ventral horns of the spinal cord, as well as supraspinally at the PAG of the midbrain and the cerebral cortex.[41,101] Changes reported at the dorsal horn include attenuation of dorsal horn neuron (DHN) hyperexcitability, or long-term depression, are evoked through the activation of myelinated high threshold (Aδ) afferent fibers.[14,102] Various studies have measured the neurosegmental effect of SMT on nociceptive flexion reflex threshold, temporal summation of thermal pain sensitivity, and pain pressure thresholds.[5,16,103] These studies indicate that mechanoreceptor stimulation may induce a 'gating mechanism' that leads to reversal of long-term potentiation within DHNs.[14,104] Similar observations have also been documented in participants with and without pain.[5,16,102] Importantly, these effects occur in tissues that are neurologically linked to the manipulated region (segmental, heterosegmental), potentially underscoring a critical clinical factor in determining which segment(s) to apply the intervention to.[5]

There are also indications that ventral horn activity may be modulated by SMT.[101] A study comparing the effects of unilateral cervical, lumbar and both cervical and lumbar SMT on tibial H-reflex amplitudes in healthy asymptomatics demonstrated significant but temporary (60 seconds) decreases in motor unit pool activity post lumbar SMT compared to cervical SMT; no additional decreases were observed when cervical SMT was also administered.[105] These regional effects are mediated by afferent input from low and high threshold mechanoreceptors within lumbar spinal and paraspinal structures, which synapse onto inhibitory interneurons responsible for regulating motor neuron activity in the ventral horn.[105] Dishman and Burke subsequently evaluated regional variations in motor neuron pool activity following cervical and lumbar SMT.[106] They reported that SMT could reduce the excitability of motor neurons in neurologically linked muscles; however,

the effects were more pronounced and long-lasting after lumbar SMT than cervical SMT.[106] They further observed similar motor neuron activity inhibition in the gastrocnemius muscle following lumbar SMT in a symptomatic population with subacute low back pain.[107] It is postulated that the inhibition of motor neuron activity and muscle hypertonicity following manipulation may be achieved by "resetting" the excitability of motor neurons via gating mechanisms evoked subsequent to large Ia myelinated afferent fiber stimulation.[104] Other modalities such as transcutaneous electric nerve stimulation (TENS)[108] and dry needling likely exploit similar mechanisms to stimulate similar neurosegmentally arranged antinociceptive effects.[5,109]

Other effects of spinal manipulation

Prior research reveals that SMT can influence neuroimmunoendocrine function. This is evidenced by its ability to modulate the immunoregulatory cytokine interleukin-2 regulated biological response[110], reduce levels of pro-inflammatory interleukin-1 and TNFa[111], and lower immunoglobulin G levels.[112] While cervical SMT had no effect on cortisol levels, thoracic SMT was found to cause a rapid and statistically significant drop in salivary cortisol levels.[113] Given that the adrenal glands are innervated by the T9-T10 segments, this observation supports the purported segmental neuromodulatory mechanisms of SMT. Serum concentrations of neurotensin and oxytocin did, however, rise briefly in asymptomatic individuals following cervical and thoracic SMT. [113–115]

An increasing body of evidence also supports the role of SMT in regulating supra-segmental function. Prior research has documented alterations in motor output and cognitive processing following manipulation.[43] Furthermore, SMT is suggested to influence the excitability of the motor cortex[116], activity of the prefrontal cortex[117], perception of joint position[118], blood oxygenation in response to harmful stimuli[119], and the function of the cerebellum[120]. Collectively, these observations suggest that SMT may have systematic neuromodulatory effects on the CNS, which could hold important therapeutic implications in the management of CS, inflammation and motor control at both spinal and supraspinal levels. However, these findings remain preliminary, and further rigorous research is necessary to confirm their clinical relevance and establish evidence-based applications.

Clinical implications

While the collective literature indicates that SMT evokes robust systematic neuromodulatory effects on somatosensory and neuroimmunoendocrine functions, the overall volume of high quality studies is still lacking, and the studies that do exist are equivocal.[121,122] One of the most significant limitations of the current studies is the universally small sample sizes across the literature. Small sample sizes reduce the statistical power of studies, making it difficult to detect true effects when effect sizes are small, increasing the likelihood of false positives or negatives, and thereby limiting the generalizability of findings. Furthermore, evidence for SMT's long-term efficacy is still lacking and requires further investigation. Long-term efficacy refers to the sustained therapeutic benefits of an intervention over extended periods, encompassing the prevention of symptom recurrence, maintenance of functional improvement, and enhancement of quality of life. The heterogeneity in observed effects from SMT may be due to differences in cohort characteristics between studies, as well as variability in the SMT techniques used (e.g., Diversified, Gonstead) between practitioners, the anatomic location of spinal adjustments, and the frequency of treatment. These factors should all be considered during the informed consent process, and may make it difficult for clinicians to provide a balanced evidence-based analysis of treatment benefit versus risk to the patient.

As a result, clinicians should strive to continuously update their knowledge through self-directed and continuing education initiatives to stay abreast of evolving knowledge trends. Additionally, they should exercise caution when communicating with patients, ensuring that informed consent discussions emphasize the current state of evidence for SMT, including its benefits, limitations, and uncertainties. Clinicians should educate patients on appropriate use of SMT and explore alternative treatment options that may reflect the patient's unique clinical presentation and history. Furthermore, clinicians are encouraged to actively participate in the advancement of chiropractic science by engaging in collaborative research and educational initiatives with researchers and other clinicians to contribute to the growing body of knowledge informing future practice. These considerations are vital to support evidence-based care and maintain patient trust.

Future directions

Future research into the mechanisms and application of SMT should incorporate a variety of strategies aiming to enhance its therapeutic utility and benefits in the context of chronic pain management. Such strategies may include exploring optimal dosing, integrating SMT with multimodal approaches such as exercise or massage, and investigating patient-specific factors like biomechanical, neurophysiological, or psychosocial characteristics that predict treatment response. Additionally, long-term studies could examine SMT's sustained efficacy and its impact on quality of life and functional outcomes in diverse patient populations. The effectiveness of SMT in the treatment of specific conditions and/or populations is a pressing and pertinent question, as it could facilitate the development of more precise and individualised treatment strategies. Identifying patient subgroups or phenotypes that are most likely to respond to SMT is essential to developing more effective treatment approaches for chronic MSK pain – a focus that some researchers have already begun exploring.[123]

Another important and relevant area of study is the assessment of the dose-response effect of SMT. This line of research should determine the most effective frequency, duration, and type of SMT for use in patients presenting with CS. Frequency refers to how often SMT sessions are performed, duration describes the length of each treatment session or overall course of care, and dose encompasses the total amount of therapeutic intervention delivered, including intensity and number of treatments. Greater insight into the dose-response relationship for specific patient subtypes or other reliable clinical biomarkers could provide additional knowledge for the advancement of personalised treatment strategies. Determining the synergistic effects of SMT in conjunction with other modalities (such as pharmacological and cognitive-behavioural approaches) will provide valuable insights into the role of SMT within the context of a multimodal approach to the management of chronic pain. Finally, although unrelated to the mechanisms and applications of SMT, developing new methods for quantifying CS is perhaps the timeliest area of study. By developing novel diagnostic tools or improving existing ones (such as QST), the clinician can accurately measure changes in CS and systematically diagnose and monitor the therapeutic progress of the patient.

Conclusion

The increasing prevalence of chronic MSK pain in society presents a unique opportunity for chiropractic to assume a leading role in the management of chronic MSK pain. CS has been linked to a broad profile of chronic pain conditions including osteoarthritis, fibromyalgia and myofascial pain syndrome, that are commonly managed within a rehabilitation setting. While the growing body of research suggests that SMT may be a safe and effective treatment option in the management of a broad profile of chronic MSK pain conditions, the mechanisms are still poorly understood. This emerging body of research characterizing the physiologic mechanisms of SMT provides an important empirical foundation supporting the increased utilization of chiropractic treatment and SMT in the ongoing management of conditions of chronic pain sensitivity.

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