MLTJ
Muscles, Ligaments and Tendons Journal

REVIEW

FUNCTIONAL TRAINING AND DUAL TASK AS A TREATMENT OPTION FOR CHRONIC LOW BACK PAIN

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Received: 22/07/2026
Accepted: 15/09/2026
Published: 29/10/2026

Conflict of interests: The Authors declare that they have no competing interest.
Fundings: None.
Contributions: The authors declare that they contributed significantly to the experimental design, data analysis and preparation of the manuscript. We declare that all authors consent with their insertion in the article. PdJS: conceptualization, investigation, original draft. JCA-S: conceptualization, investigation. DGB: review and editing, supervision. EANC: review and editing, supervision. MEDS-G: review and editing, supervision.
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LEVEL OF EVIDENCE: 5

ABSTRACT

Low back pain is the leading cause of disability worldwide. Physical exercise is currently recommended for chronic low back pain (CLBP), promoting reductions in pain intensity and improvements in physical function. Functional training (FT), defined as exercises aimed at improving performance in daily and sports activities, is a promising approach for improving trunk stability and functional capacity and may increase endogenous analgesic responses. Dual-task training (DTT), which involves simultaneous motor and cognitive tasks, may modulate pain-related circuits and activate brain areas involved in attention and cognition, potentially contributing to pain reduction. However, the pathways through which FT and DTT promote these effects remain unclear. Therefore, this narrative review aimed to discuss the possible pathways through which FT and DTT may reduce pain and improve trunk stability and functional capacity in people with CLBP. A structured search was conducted in PubMed, PEDro, and Scopus for studies published up to March 2025. Searches combined terms related to low back pain, functional training, multicomponent exercise, and dual-task training using Boolean operators. Studies involving humans with low back pain, published in peer-reviewed journals in English or Portuguese, were considered, and reference lists were screened for additional relevant studies. The evidence suggests that FT and DTT may produce complementary physiological and neurocognitive effects. However, several proposed mechanisms, particularly those involving endogenous opioids and chronic neurophysiological adaptations, remain hypothetical and require further experimental confirmation.

KEYWORDS

Chronic pain, exercise, analgesia, functional capacity, core

Publisher smc media srl

INTRODUCTION

Low back pain is the most common and disabling musculoskeletal problem in the world[1], with estimates suggesting that 80% of the global population will experience low back pain at least once in their lifetime, and about 40% will develop chronic low back pain (CLBP). The origin of low back pain is multifactorial and complex, potentially associated with micro-injuries that promote joint degeneration in the spine and damage to associated structures such as ligaments, muscles, fascia, and intervertebral discs. When these injuries are unresolved, the pain can progress to a chronic state, resulting in greater degeneration and damage, which, in turn, promote changes in the nervous system and cause central and peripheral sensitization[2], leading to increased pain sensitivity in these patients[3]. Additionally, studies show that this population exhibits decreased stability and strength of the trunk muscles[4,5] and reduced physical function[6].

Various treatment options are proposed for CLBP[7]. Physical exercise is currently recommended as the first treatment option[8] due to its ability to activate the opioid, serotonergic, immune, endocannabinoid systems, autonomic nervous system, and conditioned pain modulation, all involved in the analgesia process[9]. Moreover, physical exercise has also been proven effective in promoting increased physical function[10] in patients with CLBP. However, there is no consensus on the most effective modality; nonetheless, multicomponent modalities and those exploring dual-task situations are promising options[11,12].

Functional training (FT) is a set of exercises aimed at improving performance in daily activities through the execution of multiplanar and multi-joint exercises[13]. This modality has proven to be safe and effective for people with CLBP by promoting increased strength and endurance of trunk muscles, as well as functional capacity[14,15]. FT was specifically considered in this review because it combines multi-joint and multiplanar movements that closely resemble the physical demands of daily activities, while simultaneously targeting trunk stability, muscular strength, endurance, and functional capacity[13].

Another modality is dual-task training (DTT), which consists of performing two tasks simultaneously, either motor and cognitive or motor and motor. This modality has shown to reduce the activation of pain-related circuits while increasing activation in other brain areas related to attention and cognition[16], resulting in reduced pain intensity[11]. DTT was selected because, unlike conventional exercise approaches that primarily emphasize physical or motor components, it simultaneously challenges motor and cognitive processes, which may be particularly relevant in CLBP given the interaction between pain, attention, cognition, and motor control[17]. Therefore, FT and DTT were selected as complementary approaches, as FT primarily emphasizes physical and functional demands, whereas DTT incorporates cognitive demands alongside motor performance. Despite the beneficial effects of these training modalities, the pathways through which they exert their effects in this population are not clear. Therefore, this review investigates the possibles pathways through which FT and DTT act directly or indirectly in reducing pain, increasing trunk stability, and enhancing functional capacity in people with CLBP. Specifically, this review addresses the following research questions:

1) What physiological and neurophysiological pathways may explain the effects of FT on pain reduction, trunk stability, and functional capacity in people with CLBP?
2) What physiological and neurocognitive pathways may explain the effects of DTT on these outcomes?
3) How may the mechanisms underlying FT and DTT differ or complement each other in people with CLBP?

Since pain is a major cause of disability in this population and affects various aspects of social and work life, understanding the pathways through which physical exercise can impact this outcome is essential for more efficient prescription.

MATERIALS AND METHODS

This study is a narrative literature review. A structured search was conducted in the PubMed, PEDro, and Scopus databases, including studies published up to March 2025. The search strategy combined controlled descriptors (MeSH, when applicable) and free-text terms related to low back pain, multicomponent physical exercise, and dual-task training. Boolean operators (AND, OR) were used to refine the search. Boolean operators were applied as follows: ("low back pain" OR "chronic low back pain") AND ("multicomponent physical exercise" OR "functional training"); ("low back pain" OR "chronic low back pain") AND ("dual-task training" OR "dual-task exercise").

The study selection process was conducted in stages. Initially, titles and abstracts retrieved from the databases were screened to identify potentially relevant articles. Subsequently, the full texts of eligible studies were assessed for inclusion based on predefined criteria. Studies were included if they investigated dual-task exercise interventions and/or functional physical training in individuals with low back pain. Only articles published in peer-reviewed journals, written in English and/or Portuguese, involving human participants, and without restriction on publication date were considered eligible.

Exclusion criteria comprised studies that:

1) Addressed musculoskeletal, neurological, or systemic conditions other than low back pain (e.g., cervical pain, osteoarthritis, neurological disorders, inflammatory or rheumatological diseases);
2) Included mixed clinical populations without separate analysis for individuals with low back pain;
3) Involved postoperative populations or acute trauma; or
4) Were conference abstracts, editorials, letters, case reports, or non–peer-reviewed publications.

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In addition to the database search, the reference lists of included articles were manually screened to identify additional studies of conceptual or methodological relevance, which were incorporated to enrich the theoretical discussion. The purpose of the review was to synthesize and discuss the potential physiological, biomechanical, and neurocognitive mechanisms underlying FT and DTT, rather than to estimate intervention effects or determine the certainty of evidence.

RESULTS

Chronic low back pain

CLBP can originate from degenerative, non-degenerative, or indeterminate causes. The first is related to changes in intervertebral discs, joints, and/or ligaments. The second arises from trauma, tumors, infections, and/or spondylolysis. Finally, when the pain is not associated with any abnormality detected by imaging exams, it is defined as indeterminate or idiopathic[18].

Indeterminate CLBP is believed to result from changes in the processing of nociception and pain throughout the central nervous system, as well as structural and sensorimotor function alterations in the cortex[19]. Although evidence from human studies supports alterations in nociceptive processing and sensorimotor function in individuals with CLBP, some of the underlying cellular and molecular mechanisms have been primarily investigated using animal models. Therefore, these mechanisms should be interpreted cautiously when extrapolated to humans.

Animal model studies suggest that glial cells (microglia, astrocytes, and oligodendrocytes) are involved in the onset of chronic pain through the production of cytokines and other inflammatory mediators[20-23]. These findings provide important insights into potential mechanisms involved in chronic pain; however, the extent to which findings from animal models directly reflect the pathophysiological processes occurring in humans with CLBP remains uncertain. Specifically, in the initial phase, glial activation generates temporary hypersensitivity as a way to protect the injured site. However, when there is excessive activation or a failure to reduce this activation after the resolution of the initial problem, antagonistic effects may occur, promoting peripheral and central sensitization and, consequently, a greater perception of pain[24]. While this sequence has been demonstrated in experimental animal models, its occurrence and clinical relevance in humans with CLBP should be interpreted as a proposed mechanism rather than an established causal pathway.

This sensitization can be defined as an increased responsiveness of nociceptive neurons in the central and peripheral nervous systems to normal or sub-threshold afferent input[25]. In clinical practice, this sensitization is commonly assessed through temporal summation[26]. Temporal summation evaluates the state of hyperactivity in the dorsal horn pain facilitation pathways by applying a repetitive nociceptive stimulus with constant intensity[27]. Staud et al.[28] demonstrated that temporal summation was higher in patients with chronic pain compared to healthy controls, providing clinical evidence consistent with enhanced nociceptive facilitation in chronic pain, confirming the hypothesis that central and peripheral pain sensitization is associated with the development and maintenance of chronic pain[29].

Another important factor present in these patients is the alteration in endogenous pain modulation circuits, which involve the periaqueductal grey (PAG), rostroventromedial medulla (RVM), and the dorsal reticular subnucleus (DRt)[30]. These descending pain modulation circuits can increase or decrease the perceived magnitude of afferent nociceptive stimuli[31]. Experimentally, the functionality of endogenous pain inhibition in the CNS is usually assessed through a quantitative sensory test called conditioned pain modulation[32]. For the test, a painful stimulus is applied before and after applying another conditioning painful stimulus. When a pain modulatory system performs its physiological inhibitory role, the conditioning stimulus inhibits the pain felt during the test stimulus[31]. Lewis et al.[33], through a meta-analysis, showed that most patients with chronic pain exhibited a significant reduction in conditioned pain modulation compared to healthy controls. Another meta-analysis reinforced those patients with CLBP not only had impaired conditioned pain modulation but also significantly increased temporal summation[3].

This central and peripheral sensitization in patients with CLBP can consequently affect neuromuscular control, ligaments, tendons, and spinal muscles, which under normal conditions must work together and in a coordinated manner to maintain spinal stability. Alterations in these structures due to CLBP result in increased spinal load, potentially causing undesirable effects such as nociceptor activation and inflammatory responses, leading to even more pain[34,35]. All these changes contribute to reduced autonomy and quality of life due to decreased strength, endurance, and trunk stability[36,37], which are necessary for performing daily activities such as walking, sitting, and standing from a chair, climbing stairs, shopping, carrying, or pulling items.

The main muscles involved in lumbar stability are the erector spinae, multifidus, internal oblique, external oblique, and transversus abdominis[38]. Several studies[4,5,39–41] show that individuals with CLBP exhibit decreased coordination, muscle strength, and endurance in these muscles, leading to reduced stability and motor control. These changes are possibly due to atrophy, fat infiltration, and accumulation of connective tissue in these muscles[42]. Supporting these findings, Hodges et al. (2015)[43], in an animal model study, showed a decrease in electrical impulse in the multifidus muscle during the acute phase of pain, fibrotic changes in the subacute phase, and changes similar to disuse in the chronic phase. Although these experimental findings provide a potential mechanistic explanation for changes observed in spinal muscles following pain, direct

extrapolation to humans with CLBP should be made with caution, as the temporal progression and underlying mechanisms may differ between animal models and human conditions. All these changes together contribute to the worsening of pain and reduced function, making it necessary to propose treatments that simultaneously reduce pain and increase function. Below, two alternatives are presented along with the respective mechanisms by which each may act in the context of CLBP.

Functional training

Functional training (FT) can be defined as a set of exercises aimed at improving performance in daily activities, whether work-related or sports, through the execution of multiplanar, multi-joint exercises that are transferable to daily life activities. Additionally, FT protocols encompass different physical capacities in an integrated manner within the same session, as more than one capacity is used simultaneously in daily actions[12,44,45]. According to Da Silva-Grigoletto et al.[46] the main physical capacities stimulated include strength, power, flexibility, agility, coordination, muscular endurance, speed, and balance, all of which are necessary for performing daily activities in an integrated manner. Based on these characteristics, FT, through its emphasis on functional capacity, is a promising option for the treatment of CLBP as it specifically and integratively targets trunk (core) musculature in contexts resembling real-life situations[12].

Da Silva-Grigoletto et al.[15] demonstrated positive effects of FT on the trunk strength and muscular endurance in elderly women after 12 weeks of training, with a frequency of three times per week, conducted in a circuit format. On the other hand, traditional resistance training performed over the same period did not promote benefits in these outcomes. The authors suggest that the characteristics of FT, such as greater degrees of freedom, a range of movement speeds, and exercise instability, likely activate more spinal stabilizer muscles, improving postural control. However, this proposed increase in trunk muscle activation should be interpreted as a possible mechanism rather than a consistently demonstrated physiological response, as the magnitude and pattern of muscle activation may vary according to the exercise, task demands, training protocol, and individual characteristics[47].

Supporting this hypothesis, La Scala Teixeira and colleagues[13] assert that a key feature of FT is the application of exercises exploring different levels of instability and variations in the base of support. Moderate levels of instability can increase trunk and limb muscle activation inducing positive adaptations for muscle strength, endurance and balance[48-52]. Thus, although increased muscle activation has been experimentally observed under conditions of instability, the extent to which this response explains the chronic adaptations observed following FT remains uncertain. This feature results in a controlled stressor stimulus that may promote chronically promotes positive adaptations at the joint, muscular, and motor control levels, potentially contributing to resulting in greater stabilization and increased function[48].

From a physiological perspective, Santos et al.[12] investigated the release of β-endorphin into the bloodstream after an acute session of FT compared to a session with isolated trunk muscle exercises. It was observed that FT, acutely, promotes an increase in β-endorphin release into the bloodstream of women with CLBP. This increase in β-endorphin concentration promotes exercise-induced analgesia[53] favoring a reduction in pain sensitivity [9] during and immediately after exercise[53]. Therefore, even acutely, FT can induce immediate pain reduction, suggesting that the acute increase in β-endorphin may contribute to exercise-induced analgesia. However, evidence regarding whether repeated FT produces sustained or chronic adaptations in β-endorphin release in people with CLBP remains limited. Therefore, it is not possible to conclude that the acute β-endorphin response necessarily translates into a persistent endogenous analgesic adaptation following long-term FT. Systematically performed FT may nevertheless contribute to longer-term pain reduction through multiple mechanisms, including adaptations in sensory processing, neuromuscular function, physical capacity, and endogenous pain modulation, rather than solely through sustained increases in β-endorphin release[54]. Supporting this hypothesis, a study demonstrated that a 12-week multicomponent training program, performed once per week, was sufficient to reduce pain among a team of nurses[55].

Reinforcing the use of FT, Hayden et al.[56], in a network meta-analysis, showed that exercises aimed at increasing function are more effective in reducing functional limitations in people with CLBP compared to conservative training, such as global strengthening and aerobic exercises. The emphasis of FT on increasing function becomes evident when considering the use of basic movement patterns, such as pushing, pulling, squatting, and carrying. Additionally, this training employs coordinated patterns associated with acceleration and deceleration actions that require trunk muscle involvement, which may contribute to positive adaptations in this region and promoting increased function[15].

Supporting the use of FT, Aragão-Santos et al.[14] identified an increase in the functional fitness of elderly women after 12 FT sessions over four weeks, while concurrent training (strength + endurance) showed positive effects only after 24 sessions. Corroborating these findings, other studies have shown improvements in functional capacity, better body alignment and joint angles[57], as well as enhancements in posture and movement quality[58]. Weiner et al.[6] showed a strong association between pain duration and low physical function, endorsing the use of FT in the context of CLBP, as this training emphasizes increased physical function. Although these findings

support improvements in short- and medium-term functional outcomes, evidence regarding the ability of FT to prevent pain recurrence, reduce long-term disability, or facilitate sustained return to work remains less established. Improvements in functional capacity may be clinically relevant to these outcomes, but such relationships should not be assumed to be causal without direct longitudinal evidence. Future studies should therefore investigate whether the functional and physiological adaptations promoted by FT are maintained over longer follow-up periods and whether they translate into reduced recurrence, sustained reductions in disability, and improved work participation. *Table 1* lists the main studies involving FT, the protocols executed, and the intervention duration.

Dual task training

Dual task training (DTT) involves performing two simultaneous tasks, typically including cognitive and motor tasks or motor-motor tasks[59]. In daily life, it is common to engage in such tasks, such as cooking while talking on the phone or talking while walking. Van Daele et al.[60] demonstrated that adding a cognitive task reduced postural sway and trunk stiffness in patients with non-specific low back pain and improved their postural control. Additionally, DTT is capable of increasing trunk stability, which is significantly affected by CLBP[61]. Therefore, DTT emerges as a promising modality for treating CLBP.

Supporting the use of DTT in CLBP, Rowley et al.[62] showed that the introduction of low-intensity cognitive exercises combined with a dynamic balance task (performed using a device called the balance-dexterity device, which utilized a custom device with a spring mounted between two plates) prevented conscious processing of postural memory, resulting in better trunk coupling compared to a single-task condition in people with CLBP. These results are consistent with other studies[63,64], which demonstrated that postural sway was reduced, and posture was more stable when low-intensity cognitive tasks were applied along with motor tasks. According to Xião et al.[65], adding a low-intensity cognitive task to a motor task diverts attention from postural control and increases the automation of postural processing, thus improving trunk stability. These findings suggest that attentional allocation may influence postural control during DTT; however, the magnitude and direction of this effect may depend on the cognitive demands imposed by the secondary task.

On the other hand, some studies[62,66], have shown that postural stability decreases as the difficulty of the cognitive task increases. This phenomenon can be explained by the U-shaped nonlinear model proposed by Lacour et al.[67], which states that improvements or reductions in postural control performance depend on the cognitive task demand level. Importantly, this U-shaped relationship suggests that the interaction between cognitive demand and postural control is not necessarily linear: low-to-moderate cognitive demands may facilitate postural performance by promoting more automatic control and reallocating attentional resources, whereas excessive cognitive demands may exceed available attentional resources and impair postural control. Thus, when cognitive tasks require greater attention resources, postural control performance decreases, whereas when cognitive tasks require less attention, postural control increases. Therefore, the potential benefit of DTT may be maximized within an optimal range of cognitive demand, rather than increasing proportionally with task complexity. Consequently, it is evident that DTT can be a safe and effective option for improving trunk stability in patients with CLBP, but the complexity and demands of the cognitive task must be considered for a positive effect.

DTT has also proven effective in reducing pain intensity in individuals with CLBP. Merchant et al.[11] applied DTT twice a week over three months in elderly individuals and found reductions in pain, as well as improvements in quality of life and function. According to the authors, dual-task exercises incorporating cognitive and physical tasks activate cortical areas including the frontal, temporal, parietal, and prefrontal cortices, where opioid receptors are located, thereby reducing pain intensity. Although these findings provide a plausible neurophysiological explanation for the analgesic effects of DTT, the involvement of endogenous opioids was not directly measured in this study. Therefore, the proposed relationship between cortical activation, opioid receptor activity, and pain reduction should be interpreted as a potential mechanism rather than a demonstrated causal pathway.

Similarly, in an acute study with healthy individuals, Banticki et al.[16] examined attention-induced changes in pain perception using functional magnetic resonance imaging in healthy adults. Their results showed that individuals reported significantly lower pain intensities when engaged in demanding cognitive tasks compared to the condition without cognitive task addition. Additionally, the study found that reduced perception of painful stimuli applied during the cognitive task was accompanied by reduced activation in some key components of the pain matrix, including the insula, mid-cingulate cortex, and thalamus. Concurrently, it was found that the anterior cingulate and orbitofrontal regions involved in cognitive tasks and attention showed greater activation during cognitive interference associated with pain[16].

Cognitive engagement may act as a distraction effect inducing cognitive inhibition through selective attention attenuating pain[63]. These findings support an attentional modulation of pain perception, but they do not establish that reduced pain resulted specifically from endogenous opioid release, as the physiological activity of opioid systems was not directly assessed.

Metzger et al.[68] investigated brain activation during dual-task activities using functional near-infrared spectroscopy in healthy young adults. They observed that dual-task exercise (motor and cognitive) increased generalized

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Table 1. *Characterization of functional training used in the studies.*

Reference	Age (years)	Sex (n)	Study design	Exercises/tasks	Intervention duration	Training protocol specifications	Outcome
Da Silva-Grigoletto et al. 2019[15]	60-79	Women (45)	Randomized controlled trial	Ascending and descending steps; step jump; deadlift; alternating waves (rope); rowing; squat; medicine ball throws on the ground; push-ups; farmer's walk; run and jump between cones; pelvic elevation; run and jump between cones; movement between cones; lateral agility ladder; front plank.	12 weeks	Frequency: 3 × week Session time: 50 min each 1º block: Total time 5 min., 3-5 exercises per joint, 1 set of 8 seconds; 2º block: Total time 15 min, 5 exercises, 3 sets of 30 s, 1 min by exercise, density 1/1 intensity 6-7; 3º block: Total time: 20 min., 8 exercises, 2 sets of 8-12 repetitions, 1 min per station, density 1/1. intensity 7-9; 4º block: total time: 5 min., 5-8 efforts, density of 1/1 intensity 8-9	Increased strength and endurance of trunk muscles
Aragão-Santos et al. 2021[14]	60-79	Women (108)	Randomized controlled trial	Lateral jump; frontal jump; deadlift; single leg deadlift; rope side to side waves; rope double waves; lateral skips in agility ladder; front jumps in agility ladder; front squat; medicine ball push press overhead throw; elastic chest press; incline push up; lateral shuffle cutting; farmer's walk; pelvic lift; standing elastic row;	44 sessions	Frequency: 3 x week Session time: 1 hour each 1º block: Total time: 5 min; 1 set of 12 s per exercise; 10 squats and 10 jumping jacks; intensity 4–5 2º block: Total time: 15 min; 5 exercises; 2 rounds; 30 s of exertion/60 s of rest per exercise - Density 1/2; intensity 6–7 3º block: Total time: 32 min; 8 exercises; 2 rounds; 40 s of exertion/80 s of rest - Density 1/2; intensity 7–9 4º block: total time: 3 min; density 1/2; intensity: 8–9	Increased functional fitness
Otto and Wollesen, 2022[55]	mean age 42.5	Men (3) and women (39)	Randomized controlled trial	Warm-up and mobilization -Exercises for the mobilization of upper ankle joint, hip joint, thoracic spine, shoulder joint, and wrist joint Coordination - Feet (e.g., rotation of the tibia around the foot first in sitting, then in standing position) Hip (e.g., cat-cow) Spine (e.g., round and straighten up the back vertebra by vertebra) Shoulder blades (e.g., breathing into the shoulder blades) Head (e.g., push the head back and forth) Strength exercises - Deadlift, deadlift with a partner, hip thrust, one-legged hip thrust, standing scale, sit ups, sitting rotation, lying leg rotation, lunges, split squad Relaxation - Static stretching, self-massage (myofascial release).	12 weeks	Frequency: 1 x week Session time: 45-60 min each 5–10 min warm-up and mobilization 10–15 min coordination 30–40 min strength exercises 5–10 min relaxation Week 1–4 2×5 repetitions (deadlift) hold 2×for 60 s (hip thrust and sit ups) 2×for 30 s on each side (lunges) Week 5–8 2×5 repetitions (deadlift) hold 2×for 30 s on each side (one-legged hip thrust) 2× for 60 s (sitting rotation) 2 × for 30 s on each side (step up) Week 9–12 2×5 repetitions (deadlift with a partner) hold 2×for 30 s on each side (standing scale) 2×for 60 s (lying leg rotation) 2×for 30 s on each side (split squad)	Reduced pain and increased muscle strength
Sobrinho et al. 2023[58]	60- 70	Women (141)	Randomized controlled trial	Warm-up, balance, motor coordination, and games muscle strength training- which strengthens the regions mentioned above—such as squats, different formats of displacement (lateral, side, front, back, with high and low knees), pelvic elevation, sinks, curved row, and reverse crucifix aerobic activities relaxation	14 weeks	Frequency: 1 x week Session time: 90 min each 15 min of warm-up 35 min of muscle strength 35 min of aerobic activities 5 minutes of relaxation In each training session, ten exercises were used, with 2 min of execution and 1 min of rest. The circuit was performed twice with a 7-min water break between sets Intensity (Borg scale): weeks 1 to 2 = 3 to 4 weeks 3–5 = 4–6 weeks 6–8 = 6 to 7 weeks 9–11 = 7 to 8 weeks 11–14 = 8–10	Improvement in body alignment and joint angles.

cortical activation in the frontal, temporal, parietal, and prefrontal cortices. According to Maarrawi et al.[69], these regions have a high concentration of opioid receptors. Additionally, stimulation of the motor cortex can induce the release of endogenous opioids, providing pain relief. However, the observation of increased cortical activation during DTT does not, by itself, demonstrate increased endogenous opioid release.

Most studies cited here assessed pain perception or cortical activity rather than directly measuring endogenous opioid concentrations or receptor activity. Thus, the opioid-mediated analgesic effect proposed for DTT remains hypothetical and requires direct experimental confirmation in individuals with CLBP. Therefore, DTT, through the stimulation of these areas, may have potential beneficial effects for treating CLBP.

In addition to benefits in pain management and postural control, DTT has shown effectiveness in improving physical function. Jardim et al.[70] reported positive effects of 24 DTT sessions on the functional capacity of healthy elderly individuals compared to a control group that received educational health materials. Another study found positive effects of eight weeks of DTT on cognitive performance and gait in an older population compared to a control group receiving educational health materials[71]. Similar results were reported by Eggenberger et al. (2015)[72], who demonstrated that six months of cognitive–physical multicomponent training were effective in improving gait performance in an older adult population. Similarly, another study showed increased gait performance in older adults after twelve weeks of physical-cognitive dual task training[73]. Therefore, DTT also appears to be effective in enhancing the functional capacity of individuals with CLBP. However, DTT programs should be multi-component, similar to functional training, or at least include blocks of exercises focusing on strength, endurance, and balance. Thus, DTT is a viable and effective modality for treating CLBP, owing to its apparent effects on improving postural control, reducing pain intensity, and enhancing physical function.

This research offers practical applications, such as encouraging regular physical exercise to reduce pain intensity. Exercises that mimic daily activities can enhance physical function and reduce disability caused by CLBP. Furthermore, the study shows that adding cognitive tasks can further stimulate pain reduction by modulating attentional processes and engaging brain regions involved in pain and cognitive control. However, the specific contribution of endogenous opioid mechanisms to these effects remains uncertain, as direct physiological measurements of opioid release or receptor activity have generally not been performed in the cited DTT studies. Consequently, movement professionals have the opportunity to implement FT and/or DTT based on the specific goals for each patient. *Table 2* summarizes the main studies on DTT exploring motor and cognitive stimuli.

DISCUSSION

Both approaches are characterized by the inclusion of elements that simulate daily life demands, thereby facilitating the transfer of functional gains to everyday activities. However, while FT is predominantly structured around multiplanar and multicomponent exercises emphasizing fundamental motor patterns such as squatting, pushing, and pulling[13], DTT is based on the simultaneous performance of motor and cognitive tasks (or two motor tasks), simulating situations of attentional overload and multi-tasking demands[55].

From a physiological perspective, FT may act primarily through muscle strengthening, increasing trunk stability and generating neuromuscular and structural adaptations that may enhance postural control[14]. In this context, a systematic review demonstrated that exercises simulating daily activities, such as those proposed by this modality, require the activation of larger muscle groups[64], including the trunk muscles[13]. Furthermore, the use of unstable exercises and variations in the base of support, which are typical of functional training, may increase the activation of deep spinal stabilizing muscles, thereby potentially contributing to reduced vertebral overload and improved functional capacity[48]. There is also evidence that FT induces the release of β-endorphin, an endogenous opioid with analgesic effects, contributing to pain modulation[11]. However, whether repeated FT produces sustained adaptations in endogenous opioid release remains unclear, and the available evidence should not be interpreted as demonstrating a chronic opioid-mediated mechanism.

Conversely, DTT appears to act mainly on central pain modulation circuits and automated postural control. Studies show that performing cognitive tasks concurrently with motor execution shifts attention away from pain and/or postural control and stimulates cortical areas involved in attention, cognition, and pain modulation, such as the prefrontal cortex, anterior cingulate cortex, and insula[12]. These findings provide a plausible basis for an attentional and central mechanism of pain modulation; however, increased cortical activation does not necessarily indicate activation of a specific analgesic pathway. This activation is also associated with the release of endogenous opioids and a reduction in activity in brain regions traditionally linked to pain processing, such as the thalamus and the midcingulate cortex. Nevertheless, because endogenous opioid release or receptor activity has not been directly assessed in most of the studies cited, this opioid-mediated mechanism should be considered hypothetical rather than established. These central effects may contribute not only to analgesia but also to improvements in postural stability[60].

The reduction in pain intensity with FT may be influenced by the release of endogenous substances related to analgesia in the bloodstream, although the evidence is stronger for acute responses than for chronic adaptations. DTT, in contrast, appears to induce activation of specific

Table 2. *Characterization of dual-task training used in the studies.*

Reference	Age (years)	Sex (n)	Study design	Motor task	Cognitive task	Duration of intervention	Training protocol specifications	Outcome
Kitazawa et al. 2015[71]	70-89	Men (27) and women (33)	Experimental case control study	Walk	To memorize each step design on the basis of the instructor's demonstration.	8 weeks	Frequency: 1 x week Session time: 60 min The total time for actual walking by each participant was approximately 30 minutes in each session Participants walked 216 steps per session during the first 4 weeks of the program and 240 steps per session from the fifth to eighth weeks.	Increased cognitive performance and gait
Eggenberger et al. 2015[72]	>70	Men (16) and women (30)	Randomized controlled trial	Dance: virtual reality video game dancing. continuous flat or inclined treadmill walking (or running) Muscular strength (complement to each intervention): Examples of lower body exercises: seated leg extensions with 2 kg ankle weights, chair rises, split leg squats, calf raises (all with or without 5–10 kg weight vest), standing toe raises; two exercises per session Examples of upper-body exercises: standing arm row, biceps curls (both with resistive rubber bands), standing wall push-ups. knee push-ups; Examples of trunk stabilization exercises: incline seated single-leg raises, crunches, front plank; One to three sets with eight to 12 repetitions, progressing from slow to fast movement speed Balance (complement to each intervention): Examples: tandem stand, two-leg stand on foam pad, walking over a skipping rope on the floor, single-leg stand on air pad, single-leg stand with eyes closed	To memorize the correct sequence of 3–20 words lighting up one after the other for 3 seconds on the computer screen.	26 weeks	Frequency: 2 x week Session time: 60 min DANCE 2–3 min/game/song, 1–2 min rest periods only if required MUSCULAR STRENGTH 1 to 3 sets with 8 to 12 repetitions, progressing from slow to fast movement speed, ~1 min rest between sets BALANCE 2 to 4 sets of four to five different exercises per session, 20–60 s per exercise, 30–60 s rest Intensity: 5–7	Increased walking performance
Falbo et al. 2016[73]	65–80	Men (4) and women (32)	Randomized controlled trial	Each training session comprised a 10-minute warm-up made of walking at different speeds, light running, and moving different body segments: arms, wrists, fingers, shoulders, legs, and ankles. This part leads to a 30-minute period of coordination training (e.g., walking with arms circles), balance (e.g., maintaining a monopodalic stance with and without swinging the free leg), strengthening (e.g., squatting while extending an elastic band with arms), agility (e.g., walking through an agility ladder at different speed), followed by 20 minutes of stretching, strengthening and relaxation with exercises alternating contraction and relaxation of muscles coupled with breathing, and slow rotations of hands, head, and ankles performed lying on the floor.	During the performance of physical tasks, several features of equipment (i.e., colour and/or size of obstacles) were associated with different motor requirements and participants were required to switch randomly between stimulus-response sets.	12 weeks	Frequency: 2 x week Session time: 1 hour not informed by the authors	Increased gait performance
Jardim et al. 2021[70]	>59	Men (11) and women (61)	Clinical trial	Functional Circuit + Walking Resistance training Dance	To speak out loudly the days of the week, months of the year, and the alphabet in direct and reverse order To remember pre-selected words and sing songs with the vocabulary included At functional physical exercise circuit beginning, researcher reads a word sequence (places, animals, and objects), which were requested to be reproduced by the participant at the circuit endpoint Simple calculations (arithmetic) The group was encouraged to remember and to speak out loud words from a certain category or phoneme.	12 weeks	Frequency: 2 x week Session time: 75 min warm-up (10 min), aerobic exercise (30 min), resistance exercise (30 min), and stretching (5 min). Intensity 60–70% of the maximum heart rate estimated using the Karvonen formula	Increased physical fitness and quality of life

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areas in the central nervous system involved in reducing pain intensity. However, the distinction between FT as predominantly "peripheral" and DTT as predominantly "central" should be understood as a proposed conceptual model rather than as evidence that either modality acts exclusively through one physiological pathway. Both modalities are likely to involve overlapping peripheral, spinal, and supraspinal mechanisms. Furthermore, FT has been shown to improve functional capacity due to its emphasis on exercises with movement patterns similar to those used in daily life activities, such as squatting, pulling, pushing, and carrying. Although several studies report beneficial effects of FT and DTT, not all interventions produce significant improvements across all functional, pain, or cognitive outcomes. Differences in exercise dose, intervention duration, baseline functional status, cognitive task complexity, adherence, outcome measures, and participant characteristics may partly explain these heterogeneous findings. Therefore, the available evidence supports potential benefits rather than universal effects across all individuals with CLBP. Despite the differing mechanisms, both protocols may be beneficial for individuals with chronic pain, allowing professionals to select and adapt between options based on patient preference, clinical characteristics, treatment goals, and professional expertise. The proposed interactions between FT and DTT related mechanisms and their potential contributions to pain modulation, trunk stability, and functional capacity are summarized in *Figure 1*. Regarding clinical application, FT requires a greater focus on the controlled and progressive execution of functional movements with an appropriate level of challenge, often structured as circuit training. In contrast, DTT requires careful planning of the complexity of cognitive tasks, as excessive cognitive demands may compromise postural stability and attenuate the expected benefits[67].

Patient selection is also an important consideration when applying either modality. Although FT and DTT appear promising for individuals with CLBP, their effects should not be assumed to be equivalent across different clinical profiles. Patients with severe disability may initially require lower-intensity, simpler, and more individually supervised exercises before progressing toward complex functional or dual-task activities. In older adults, DTT may be particularly relevant because cognitive-motor interactions are important for mobility and activities of daily living; however, task complexity should be progressively adjusted according to cognitive and motor capacity. Similarly, in individuals presenting greater pain sensitivity or features suggestive of altered nociceptive processing, initial exposure to highly demanding tasks may not be appropriate, and exercise intensity and cognitive load may need to be gradually progressed according to tolerance. Thus, baseline functional capacity, pain severity, cognitive status, balance, motor control, and individual goals should be considered when selecting and progressing FT or DTT.

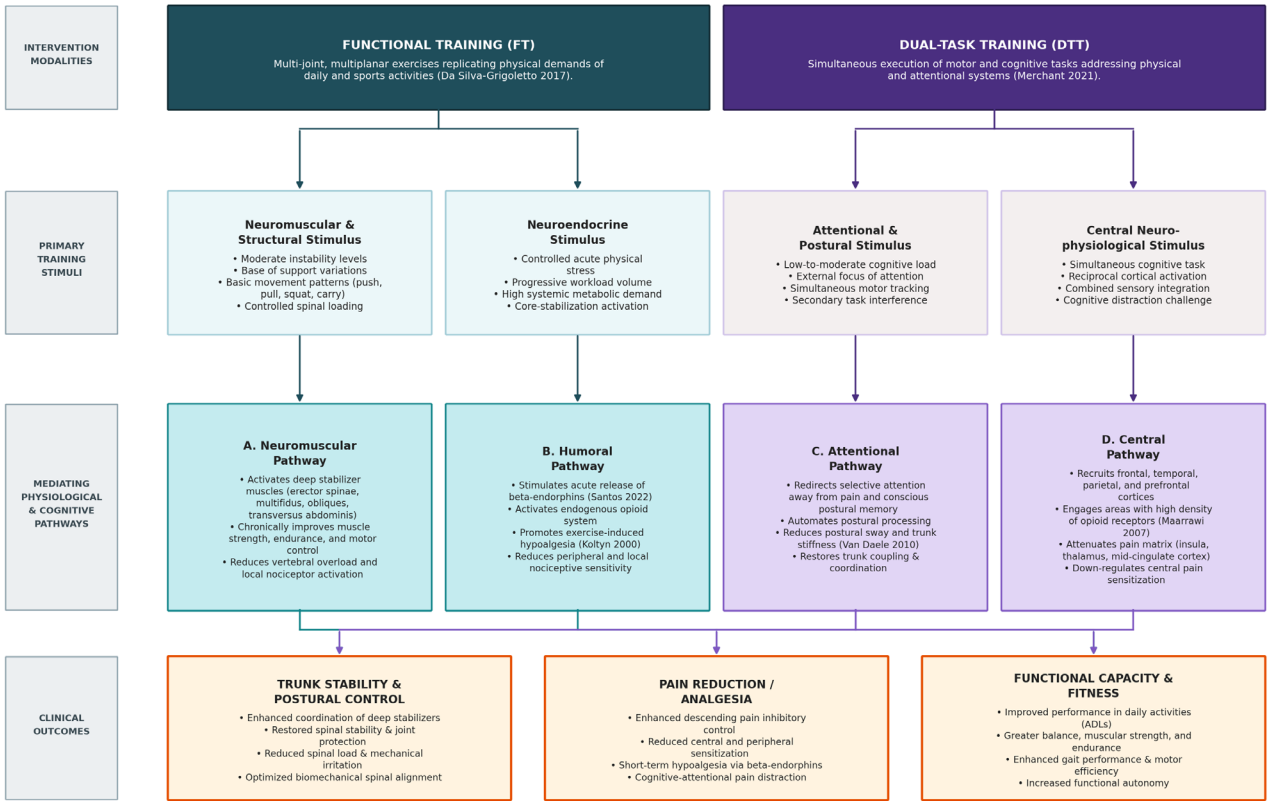


Figure 1. *Proposed mechanisms of FT and DTT in CLBP. Both approaches may promote complementary and overlapping mechanisms involving neuromuscular, attentional, cognitive-motor, and pain-modulatory processes, potentially improving pain, trunk stability, and functional capacity. Some proposed mechanisms remain hypothetical and require further experimental confirmation.*
Abbreviations: CLBP, chronic low back pain; DTT, dual-task training; FT, functional training.

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In summary, FT and DTT share the ability to potentially reduce pain and improve function in individuals with CLBP, although they may emphasize different, but overlapping, mechanisms, with FT placing greater emphasis on peripheral and neuromuscular adaptations and DTT placing greater emphasis on central, cognitive, and attentional processes. This distinction should be interpreted as a proposed conceptual framework rather than an established dichotomy. This complementarity can be explored in clinical practice to foster more effective and personalized interventions, provided that exercise demands are appropriately matched to the patient's clinical profile and progressively adjusted according to response and tolerance.

CONCLUSION

FT and DTT have shown potential benefits in reducing pain intensity, improving trunk muscle function, and enhancing the functional capacity of individuals with CLBP. However, it is worth noting that the pathways through which these training methods may benefit this population are likely to involve overlapping and complementary mechanisms, and the distinction between their proposed mechanisms should not be interpreted as an established physiological dichotomy. FT appears to enhance motor control due to its direct action on improving trunk activation, strength, endurance, and stability, given its focus on multi-joint and multi-planar exercises that require trunk muscle involvement. Although improvements in trunk muscle function and functional capacity have been experimentally demonstrated, the specific mechanisms responsible for these adaptations, including the extent to which increased trunk muscle activation mediates clinical improvements, remain incompletely understood. On the other hand, DT may divert attention from postural control and promote greater automation of postural processing, potentially resulting in a lower perception of pain. Evidence supporting attentional modulation of pain and changes in cortical activity provides a plausible basis for this mechanism; however, the contribution of endogenous opioid release remains theoretical in the absence of direct physiological measurements in most studies.

Therefore, established findings regarding improvements in pain, muscle function, and functional capacity should be distinguished from the proposed physiological and neurocognitive pathways underlying these effects. In particular, mechanisms involving chronic adaptations in β-endorphins, endogenous opioids, central sensitization, and changes in cortical processing should be interpreted as plausible hypotheses rather than confirmed causal mechanisms.

We suggest that future studies investigate the physiological and biochemical mechanisms involved in pain reduction, such as the chronic effects of exercise on β-endorphins and other markers. Future research should also prioritize well-designed randomized controlled trials directly comparing FT and DTT in individuals with CLBP, using comparable training duration, frequency, and exercise dose. Such studies should include standardized measures of pain intensity, disability, trunk muscle function, functional capacity, and endogenous pain modulation, as well as adequate long-term follow-up to investigate the maintenance of treatment effects, pain recurrence, and disability. Where feasible, direct physiological measurements of β-endorphins and other neurochemical markers, together with neuroimaging or neurophysiological measures, could help determine whether the proposed peripheral, central, and cognitive mechanisms are actually involved in the clinical effects of these interventions. Additionally, research emphasizing biomechanical aspects could contribute to scientific literature on the effects of specific exercises on increasing stability and motor control of the spine and their impact on the functional fitness of individuals with chronic pain. Comparative studies should also investigate whether particular patient profiles, levels of disability, pain sensitivity, age, or cognitive-motor status respond differently to FT or DTT, thereby supporting more individualized exercise prescription.

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