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Review

Mechanism of action of spinal manipulative therapy

Jean-Yves Maigne [a,*], Philippe Vautravers [b]

[a] *Physical Medicine Department, Hôtel-Dieu Teaching Hospital, Place du Parvis de Notre-Dame, 75004 Paris, France*
[b] *Physical Medicine Department, Hautepierre Teaching Hospital, Strasbourg, France*

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Abstract

Spinal manipulative therapy (SMT) acts on the various components of the vertebral motion segment. SMT distracts the facet joints, with faster separation when a cracking sound is heard. Intradiscal pressure may decrease briefly. Forceful stretching of the paraspinal muscles occurs, which induces relaxation via mechanisms that remain to be fully elucidated. Finally, SMT probably has an inherent analgesic effect independent from effects on the spinal lesion. These changes induced by SMT are beneficial in the treatment of spinal pain but short-lived. To explain a long-term therapeutic effect, one must postulate a reflex mechanism, for instance the disruption of a pain–spasm–pain cycle or improvement of a specific manipulation-sensitive lesion, whose existence has not been established to date.

Keywords: Spinal manipulative therapy; Low back pain; Manual medicine; Chiropractics; Osteopathy

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1. Introduction

Spinal manipulative therapy (SMT) has been proved effective in alleviating acute low back pain and may help to improve neck pain, sciatica, and chronic low back pain [1,2]. The definition of SMT is not agreed on and varies across specialties (osteopathy, chiropractic, and medicine). The term is sometimes used to designate all manual treatments, including soft tissue techniques, mobilization (or low-velocity high-amplitude manipulation), and thrust manipulation (or high-velocity low-amplitude manipulation). Others reserve the term SMT for thrust manipulation, defined as a passive movement that tends to nudge the components of a joint or group of joints beyond their usual physiological range [3]. In short lever manipulation (direct techniques), the thrust is delivered directly to the vertebra, whereas in long lever manipulation it is delivered elsewhere, for instance to the scapular or pelvic girdle. Short lever techniques were developed by chiropractors and long lever techniques by osteopaths. Their mechanism of action is only partly understood and is clearly more complex than a simple "readjustment" of the vertebras, a misconception that still carries weight with the general public. We reviewed the literature on the effects of manipulations on each of the constituents of the vertebral motion segment. The conclusions call into question a number of widely held beliefs about SMT.

2. Effects on the vertebral motion segment

2.1. Effects on the vertebral bodies

The thrust is applied either to a part of the patient's body that acts as a lever or directly to a transverse or spinous process. A modest part of the thrust is absorbed by the paraspinal soft tissues and the rest is transmitted to the spine [4], mobilizing the vertebras on one another. This has been shown in the cadaver studies using needles inserted into thoracic vertebras [5], or accelerometers secured to the lumbar vertebras [6]. The maximum amplitude of the movement is reached at 0.1–0.5 s after the thrust [4]. Although textbooks describe manipulation as targeting a single vertebral level, studies have shown that several levels are mobilized simultaneously, i.e., either the levels adjacent to the manipulated level after short lever manipulation [7], or the entire lumbar spine after long lever manipulation applied to the lumbar spine [6]. The induced movement is complex because several vertebral movements occur in combination and manipulation applies nonphysiological forces that can produce unusual displacements [6]. When properly relaxed, the muscles do not seem to oppose noticeable resistance, as the high velocity

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* Corresponding author.
E-mail address: jy.maigne@htd.ap-hop-paris.fr (J.Y. Maigne).

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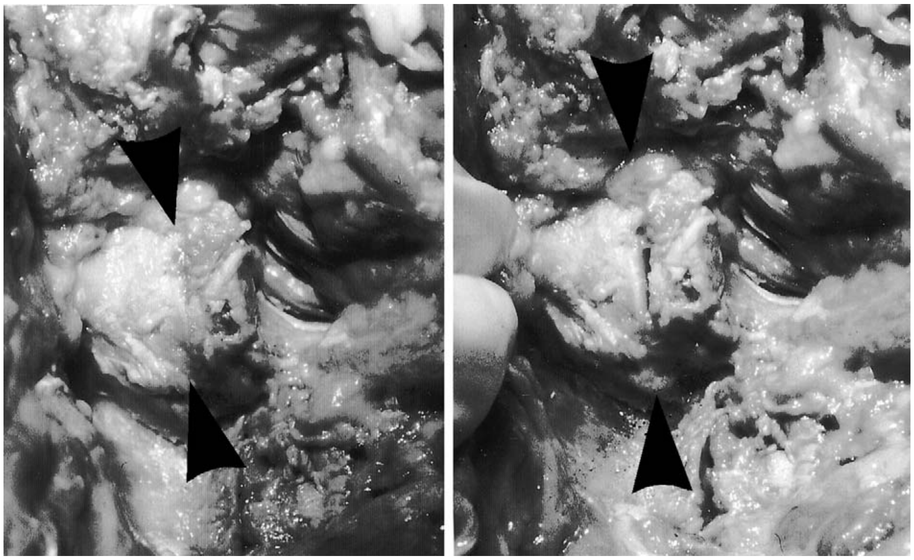

Fig. 1. Gapping of the L4–L5 facet joint induced by manipulation, seen after incision of the capsule. Such gapping is not obtained during physiological rotation.

of the thrust does not allow enough time for a splinting reaction to develop [4,7,8]. Conversely, paraspinal muscle spasm can make manipulation impossible.

2.2. Effects on the facet joints

2.2.1. Experimental evidence

The cracking sound characteristic of SMT is related to cavitation of a facet joint. Cavitation has been studied at the metacarpophalangeal joints [9]. When traction is applied to a joint that does not crack, the surfaces separate gradually and at constant speed. With cracking joints, on the contrary, cohesive forces prevent separation until the traction is sufficiently strong to create a pressure decrease within the joint; this leads to the formation of gas and vapor bubbles and sudden separation of the joint surfaces at a very high speed, displacing the joint fluid to the low-pressure areas. The resulting reduction in the gaseous phase within the joint cavity produces a cracking sound. This sequence can be transposed to the spine. At the beginning of the thrust, the facet joint surfaces adhere to each other and the vertebras remain interdependent. During physiological rotation, the separation of the facet joint surfaces does not occur [10]. When the force of the thrust exceeds a threshold, separation occurs suddenly, with cavitation of the joint and a cracking sound. This separation is visible in cadavers (Fig. 1). Thus, energy builds up initially before being abruptly released as high-velocity separation of the joint surfaces. The velocity of the separation is greater than that of the thrust. Joint cavitation, which can be compared to the sudden giving way of a spring that is stretched forcefully, is characteristic of SMT.

2.2.2. Clinical applications

SMT is often described as acting mainly on facet joint pain [11], although there is no evidence that this is true. Joint surface separation may release entrapped synovial folds [12,13] or intraarticular adhesions that limit motion [14]. These mechanisms are hypothetical, and there is no proof that adhesions cause pain. Conversely, joint capsule stretching (by intraarticular saline injection) has been shown to inhibit paraspinal muscle spasm (see below) [15].

2.3. Effects on the intervertebral disk

2.3.1. Experimental findings

Intradiscal pressure changes have been shown to occur during SMT. At the beginning of the thrust, the pressure increases as the two adjacent vertebral bodies are brought closer to each other, probably because the rotational component of the manipulation exerts traction on the oblique annular fibers. At the end of the thrust, the traction predominates, separating the vertebral endplates and decreasing the intervertebral pressure below the baseline value [6]. The pressure returns to baseline less than a minute. These data, which were obtained in two cadavers, need to be confirmed by studies in vivo.

2.3.2. Clinical applications

These findings suggest that SMT may produce pain relief in some patients with disk-related back pain. Entrapment of a nucleus fragment in a radial crack in the anulus may explain some cases of acute low back pain or disk pain [16,17]. SMT may return the fragment to its central position by separating the endplates, pulling on the posterior longitudinal ligament, and diminishing the intradiscal pressure [12,13,18]. This mechanism, which is hypothetical, may return the protruding disk material to its normal position, or at least to a position further from the nerve root [3]. Unfortunately, this has not been documented after SMT [18,19]. The observation by Adams et al. [20] that stress concentration peaks occur in the lumbar disks may provide a more convincing explanation to the effects of SMT on the disks. Sustained loading of a disk generates pressure peaks, particularly in the posterior anulus, corresponding to areas of high stress concentration. These

Fig. 2. Lumbar spine manipulation with the patient lying on the left side. Top: in the starting position, the tension is symmetric in the two erector spinae muscles. Bottom: after manipulation, the left muscle is stretched and the right muscle is relaxed.

peaks may cause pain by activating nerve endings in the anulus and endplates. The brief drop in intradiscal pressure induced by SMT may diminish the amplitude of the pressure peaks [6]. In vivo studies are needed.

2.4. Effects on the paraspinal muscles

2.4.1. Experimental data

An effect of SMT on the paraspinal muscles has long been suspected [3]. In general, paraspinal muscle stretching is more marked with long lever techniques than with short lever techniques [3]. For instance, loading during long lever manipulation stretches the paraspinal muscles and psoas on the side that is on the table and relaxes them on the other side (Fig. 2) [21]. The thrust is followed by separation of the facet joints and vertebras, which further increases the stretch. This may lead to relaxation of the paraspinal muscles via three documented mechanisms.

The first mechanism occurs at the lumbar level and seems related to stretching of the psoas muscle. Stretching of a flexor muscle (here the psoas), particularly when slow and gradual, inhibits the motor neurons innervating the antagonists (here the paraspinal muscles), via reciprocal Ia inhibition [22]. Furthermore, forceful stretching activates the Ib fibers of the flexor muscle, thus inducing presynaptic inhibition of the afferent Ia fibers of the agonists [23], which contributes to reduce the activity of extensor muscle alpha motor neurons. We believe this may explain the short-term attenuation in alpha motor neuron activity responsible for the decreased amplitude of the tibial nerve H reflex seen after sacroiliac or lumbar manipulation [24,25]. This inhibitory effect occurs at 1.5–2 s after the thrust and lasts less than 1 min.

Whether it also affects the paraspinal muscle motor neurons remains unknown, but the innervation comes from the same spinal cord level.

The second mechanism is paraspinal nerve stretching and may have two effects. High-velocity direct thrusts (lasting less than 200 ms) are followed after only 50–200 ms by reflex contraction of various back muscles, often at a distance from the manipulated area [26]. The early occurrence of this effect rules out voluntary participation of the patient. This brief (less than 400 ms) reflex contraction following stretching of the muscle may contribute to reduce muscle spasm [26]. Furthermore, postactivation depression may also be involved. This phenomenon, first described after passive stretching of the triceps surae, involves stimulation of Ia and II fibers, which activates the motor neurons via a chemical neurotransmitter. Transient depletion of the neurotransmitter ensues, so that excitability of the motor neurons is reduced for 12–15 s after stretching [27–29]. This phenomenon has also been documented at the upper limbs and probably occurs in the paraspinal muscles, since these contain an abundance of neuromuscular spindles. Stretching of the paraspinal muscles during manipulation, related to the position of the patient and to application of the thrust, may be followed by relaxation.

The third mechanism may be related to stretching of the facet joint capsules, which has been shown to blunt the motor unit action potential of the paraspinal muscles [15].

2.4.2. Clinical applications

Tenderness and tension of the paraspinal muscles are common in patients with back pain. The result is a decreased range of forward bending of the spine. In patients with low back pain, a lasting decrease in this painful paraspinal muscle tension has been documented after SMT, using a variety of techniques [30–32]. This indicates that the short-lived effects of SMT on muscle tone translate into long-lived changes, a point that is discussed below.

2.5. Effect on pain

2.5.1. Experimental data

By suddenly stretching the ligaments, disks, joint capsules, or muscles, SMT may activate the diffuse descending pain inhibitory system, whose neurons are located in the periaqueductal gray matter [33,34]. This central, nonspecific mechanism explains why pain can be relieved by nociceptive stimulation at another site [35]. Furthermore, forceful muscle stretching induces presynaptic inhibition of afferents from the skin [28], which may explain why the local cutaneous pain threshold increases after spinal manipulation but not after a placebo [36]. Finally, modest but significant elevations in plasma beta endorphin levels have been found 5 min after cervical SMT [37].

2.5.2. Clinical applications

A nonspecific analgesic effect is beneficial, but two pitfalls must be avoided. SMT has been reported to produce transient pain relief in patients with undiagnosed vertebral metastases [38]. SMT in patients with vertebral metastases can lead to serious complications. Furthermore, relief of pain in a shoulder, elbow, or knee after SMT is not proof that the pain originates in the spine.

2.6. Effect on blood flow

Increasing the blood flow to organs is among the main objectives of traditional osteopathic therapy [39]. Increased blood flow may promote clearance of toxic substances, thereby inducing benefits in many diseases. In patients with disk-related sciatica [40] or chronic neck–shoulder pain [41], decreased blood flow has been documented in the involved area, and atherosclerosis has been found in association with degenerative disk disease [42]. There is no proof, however, that SMT increases blood flow or that such an increase would be beneficial. In a randomized controlled study, SMT had no effect on vertebral artery flow [43].

2.7. Placebo and psychological effects

As with all treatments, a placebo effect occurs with SMT. A feeling that the vertebra has been returned to its normal position, a perception that the cracking sound indicates effectiveness, and the manual contact preceding the manipulation all contribute to the placebo effect. In addition to this psychological effect, many spinal pain syndromes improve spontaneously. Finally, patients may perceive the explanations supplied by SMT practitioners as more satisfactory than those given by physicians [44].

3. Considerations about the mechanism of action of manipulation

3.1. Is there a specific "manipulable" lesion?

The beneficial effect of SMT suggested by the literature invites a discussion of the target of SMT. Historically, manipulation was believed to target a specific "manipulable" lesion, although this concept varied across schools and over time. "Subluxation", "fixation", "osteopathic lesion", "somatic dysfunction", and "intervertebral derangement" are the names most often used. None of these lesions have been convincingly documented. A more recent hypothesis involving a return to normal anatomic position of a vertebral motion segment that has buckled in response to loading [14] has been suggested based on experimental findings [45]. However, a study of the sacroiliac joints found that manipulation failed to alter the position of the sacrum in relation to the ilium [46]. Another hypothesis stems from the finding that the facet joints at the thoracolumbar junction are slightly asymmetrical in some patients. This may affect rotation and lock the affected spinal level in an abnormal position [47,48]. However, if these specific lesions exist, they are present in only a small minority of the patients who experience benefits from SMT. Thus, the presence of "manipulable" lesions cannot fully explain the effect of SMT.

Another explanation may involve an effect of SMT on disk pain. Painful tension of the paraspinal muscles is the rule in patients with disk disease. However, the muscle effects of SMT last less than a minute, which indicates that the disruption of a pain–spasm–pain cycle is probably involved in the long-term effects. This mechanism may be particularly important when painful paraspinal muscle tension persists in a patient with a minor disk lesion (e.g., a marginal tear in the anulus) that has started to heal. Animal studies have shown that intense activation of a simple cord reflex (as simple as pain–spasm) can lead to the conditioning of the synapse of the afferent fiber on the motor neuron. This conditioning explains the persistence of an abnormally strong motor neuron response, for up to several months, even when the initiating stimulus is minimal or no longer present [49]. Thus, SMT may be particularly effective when the original lesion is modest or has healed, the mechanism being relief of the painful paraspinal muscle tension. In agreement with this possibility, manual treatment for coccydynia has been found more effective in patients with normal radiographs than in those with radiographic lesions [51].

3.2. The thrust

There is no experimental evidence that thrust manipulation is better than simple mobilization. Slow gradual stretching can produce marked elongation of the psoas and paraspinal muscles. Yet, most clinical studies have focused on thrust manipulation, which is felt by most chiropractors to increase efficacy. Comparative studies are in order.

3.3. Rules for application

The indications of SMT and of its various techniques vary across schools of thought. According to the lesion felt to be responsible for the pain, SMT seeks either to return a vertebra to its normal position or restore lost mobility. Rather than specific lesions, the French school uses an empirical rule based on freedom from pain and contrary movement [50]: the manipulation is done in the opposite direction to the movement that causes pain. Improvements in the knowledge of the mechanism of action of SMT suggest that at least three anatomic effects should be sought: on the side of the pain (determined by the physical examination), the facet joint surfaces should be separated, the paraspinal muscles (and psoas muscle at the lumbar level) should be stretched; and the intradiscal pressure should be lowered. Selection of the optimal type of manipulation for a given patient should be based on these goals. Manipulative techniques probably vary in their ability to stretch the paraspinal muscles, decrease intradiscal pressure (by increasing lumbar lordosis), and gap the facet joints, and deeper differences probably exist between chiropractic and osteopathic techniques [51].

Researchers investigating manual techniques should strive to elucidate the biomechanical consequences of each manipulative technique on the vertebral motion segment.

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