PHYSIOLOGICAL EFFECTS OF SPINAL MANIPULATION:
A REVIEW OF PROPOSED THEORIES

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ABSTRACT

High velocity low amplitude thrust (HVLAT) or manipulation is commonly used for the
treatment of back pain. This critical review of the proposed mechanisms of action was based on
a database search using the keywords: spinal manipulation, low back pain, osteopathy, physio-
therapy and chiropractic. Three proposed mechanisms were highlighted – biomechanical,
muscular reflexogenic, and neurophysiological. There is evidence of a mechanical gapping of the
facet joints during manipulation, although the clinical significance of this is not clear. There is
also evidence to support the theory that HVLAT techniques evoke spinal stretch reflexes
resulting in a brief muscle contraction possibly followed by a period of reduced muscle activity.
The papers also provide support for the anti-nociceptive treatment effects of HVLAT and this
would have obvious benefit to the patient. In conclusion, there is support in the literature for each
of the mechanisms, but it is clear that more research is needed to further our understanding of the
mechanisms underlying spinal manipulation.

Keywords: Spinal manipulation, osteopathy, physiotherapy, chiropractic, low back pain

INTRODUCTION

Spinal manipulation is a commonly used treatment modality for the management of low back pain. Manipulative treatments have been recorded since Hippocrates in 400 BC, who wrote of their value in treating spinal misalignment. There are also some records of spinal manipulation treatments dating back to 2700–1500BC from China and Greece. Today, spinal manipulation is used by physiotherapists, chiropractors, osteopaths, and some medical practitioners.

There have been numerous trials and reviews of the efficacy of spinal manipulation which provide the basis of evidence to support its use in clinical practice. However, despite the long-term, historic use of spinal manipulation, and its current recommendation as a treatment for the management of acute low back pain, there is poor understanding of the physiological mechanism by which it may achieve its therapeutic benefit. This critical review considers the current theories proposed to explain the physiological mechanism of spinal manipulation and discusses their validity.

METHODOLOGY

A search of the Medline, AMED and Cinahl databases was carried out including papers up to September 2004. The following keywords were used: spinal manipulation, osteopathy, physiotherapy, chiropractic, and effects. Pertinent references were obtained by hand searching the bibliographies of the retrieved literature and these were also reviewed. When examining the current literature, the reported
trials often use a mixture of manipulative interventions from passive joint stretching to high velocity low amplitude thrusts (HVLAT). In this review, only those spinal manipulation studies relating to HVLAT were considered. Seventy-one abstracts were identified and read from the original database search and, from these, 31 papers were retrieved and reviewed.

RESULTS

Reviewing the literature highlighted three main theories as to how spinal manipulation might produce its therapeutic benefit (either through one or more of the following mechanisms) – biomechanical, muscular reflexogenic, and neurophysiological. These are considered separately below.

Biomechanical effects

Joint gapping

One of the most commonly held beliefs concerning how HVLAT techniques might influence function are that they have a biomechanical effect. Sandoz7 performed a study looking at finger joint (metacarpophalangeal) distractions, and showed that distractions causing cavitation (which is the noise or ‘crack’ heard during HVLAT), increased the radioulnar joint space. This was associated with a 5–10° increase in the range of movement at the joint; once cavitation had occurred, it could not be repeated within 20 min. Cavitation is the term used to describe the formation of gaseous bubbles or cavities within the synovial fluid of the joint, as a result of a distraction that causes a local reduction in pressure.

Méal and Scott8 and Conway et al.9 have since performed studies looking at the sounds from these finger joint distractions and compared them with the sounds from facet joint cavitations in the spine. By comparing the sound signals, they proposed, given that nature of the sound waves were similar in the finger distraction to the facet joint manipulations, that a similar event must occur in both joints. They inferred from this that facet joints also show an increase in joint space following HVLAT.

The more recent study by Cranmer et al.10 provides further evidence for an increase in joint space following HVLAT, as measured by MRI scanning. Sixteen healthy volunteers were scanned, then placed in a side-lying position and finally re-scanned; half received a HVLAT before being re-scanned. The authors demonstrated that the average change in joint separation (noted between three radiologists) for the manipulation group was +1.2 mm, whereas in the control group the average change was only +0.3 mm. The authors compared their experimental findings with the maximum forced gapping of the facet joints in dried skeletal vertebral columns. In dried specimens, the gapping is small due to interlocking of the articular processes, so the authors considered the changes measured in the intervention group to be dramatic and likely to be clinically significant. These results are consistent with the hypothesis that spinal manipulations cause a biomechanical separation of the facet joint within hypomobile joints. However, these results must be treated cautiously as the study was conducted on a small sample size; further work on a larger group could potentially provide additional evidence for the biomechanical effect of HVLAT.

Improved range of movement

Historically, authors supporting the theory that spinal manipulation improves a joint’s range of movement used the above evidence to support their ideas. Lehman and McGill11 were able to demonstrate small changes in range of movement following spinal manipulation and noted the biggest increases were seen in those subjects who had the greatest degree of pain. The authors argued that improved range of movement is of benefit in creating a window of opportunity to exercise and improve physical function, but there is as yet no direct evidence from the literature that this occurs.

Muscular reflexogenic effects

The reflexogenic effect is thought to produce a reflex reduction in pain, muscle hypertonicity, and improvement in functional ability. There are three papers which examine the muscle reflex response which occurs during HVLAT. Herzog et al.12 described an experiment which measured the electromyographic (EMG) reflex response to spinal manipulation in a small group (n = 10) of asymptomatic men. This group was able to demonstrate a consistent and systematic reflex response both in muscles local to the manipulated joint and also in more distant muscles. The authors considered a reflex to have occurred if the EMG during the manipulation rose to at least 3 times the resting baseline EMG level; the authors estimated the latency of the reflex response to be about 50 ms. Symons et al.13 repeated the experiment, this time using an activator device to deliver the thrusts resulting in a more localised, mainly ipsilateral, reflex response with a much shorter latency (on average 4 ms). Again, a reflex response was considered to have occurred if the EMG during the HVLAT rose to 3
times the resting EMG level. Colloca and Keller subsequently performed a comparable experiment, using an activator device, but this time on low back pain patients \((n = 20)\). They normalised the EMG reflex response against that obtained during a maximal voluntary contraction. The authors showed that again a reflex response was elicited, and that those patients who had the greatest degree of pain and disability had the largest amplitude of reflex response. The latency was again given as about 4 ms.

These papers provide some evidence for the existence of a transient reflexic muscular contraction as a response to spinal manipulation. However, without the use of a control group, these experiments do not show whether this reflex is actually due to the joint manipulation, and is not simply an artefact caused by some other part of the intervention. Furthermore, they do not provide any information on the clinical and therapeutic relevance of these transient muscle reactions.

Spinal stretch reflexes have been widely studied, and it is known that a distinct pattern of events occurs when a muscle is tapped or stretched, although the origin of later responses is subject to some debate. Several authors have investigated the effects of tapping paraspinal muscles; first, a wave of activity occurs on the EMG trace termed \(R_1\), which has a latency of approximately 10–20 ms. This is a bilateral response with the contralateral response being of the same or smaller amplitude, but being less consistent. This is followed by a period of EMG silence (for up to 200 ms), in which a second wave of activity can be seen (termed \(R_2\); generally smaller than \(R_1\)); again, this is a bilateral phenomenon where the contralateral response is of the same size or larger than the ipsilateral response, and it has a latency of about 30–50 ms. \(R_1\) with its short latency is likely to be representative of the monosynaptic segmental reflex loop, whereas the longer latency of \(R_2\) has been attributed to long loop reflexes indicative of the involvement of supraspinal influences.

Herzog et al. proposed that reflex responses were seen in muscles distant to the joint being manipulated, due to mechanical propagation of the manipulation impulses. This view is supported by the study of Lance and De Gale’s which examined spinal reflexes evoked by tapping muscle and bony points. Tani et al. considered that, as the transmission speed of these reflexes was similar to that known to occur in the fast conducting dorsal columns, this was a possible mechanism for the transmission of the \(R_2\) reflex responses. Short latency reflex responses are seen in distant muscles due to a local segmental monosynaptic reflex response being initiated, when the propagated vibration arrives at the distant muscle.

An experiment examining spinal reflexes in scoliotic patients showed that reflexes were facilitated if the muscle was tonic, which is also seen if the subject is making a voluntary contraction when the reflex is evoked. These findings are consistent with the reduction in the stimulation threshold for the alpha motor neuron caused by increase in tonic activity. Furthermore, in experimentally induced pain, the reflex responses are also facilitated. This would help to explain the finding of Colloca and Keller that, in those patients with the most pain, the amplitude of the reflex response was significantly larger. This evidence provides support for the existence of a transient reflexic muscular contraction as a result of HVLAT.

The finding by Herzog et al. of a reflex with a 50-ms latency, which indicates a long loop reflex, lends support to the theory that there might be a supraspinal influence as a result of manipulation.

Both Symons et al. and Colloca and Keller demonstrated a latency of only 4 ms which brings into question the origin of this response. In other experiments looking at stretch reflexes in paraspinal muscles, the short loop \(R_1\) has a latency of 10–15 ms; therefore, this shorter latency response seen after the use of an activator device might simply be an EMG artefact.

Mechanisms for modulation of alpha motor neuron activity

There is a widely held perception that back pain leads to muscle hypertonicity, and that spinal manipulation results in a reduction in muscle tone; however, the evidence to support this is poor. There is some debate as to whether subjects with low back pain have altered EMG activity, as measured at rest, as both hyper- and hypo-activity have been reported. Furthermore, Hubbard et al. reported no significant difference in the EMG signals from muscles which were tender to palpation, and those which were non-tender during a static examination. Some studies have shown alteration in recruitment of paraspinal muscles during dynamic postures, especially a reduction in flexion/relaxation phenomena. During full flexion of a healthy subject there is an EMG silence, as it is thought that the spine is held in this position by the posterior ligamentous system of the spine and muscle activity becomes negligible. A likely explanation for this difference is provided by Ahern et al. who commented that a majority of the low back pain patients in their study did not manage to achieve the range of flexion necessary for the relaxation to occur thus preventing the phenomena occurring. However, there is a considerable body of evidence that the paraspinal muscles operate submaximally in back pain patients, causing a decrease in endurance and decrease in strength.
Changes in muscle activity post manipulation

Little work is reported in the literature regarding changes in muscle activity after manipulation. Herzog et al.12 offered evidence for the reduction in muscle EMG activity post manipulation in a single case study. Similarly, Lehman and McGill28 reported a single case where the EMG fell from 22% to 13% of the sub maximal voluntary contraction, whilst overall their experiment (n = 14) showed little or no change in EMG measurements post manipulation. Ellestad et al.29 reported that EMG activity reduced over the course of a week following osteopathic HVLAT, although a series of treatments was used, so it was not possible to see which component of the treatment might have been responsible for this change.

Dishman and Bulbulian39 showed a transient reduction in alpha motor neuron activity as measured by the Hoffman reflex (H reflex) after spinal manipulation, but not after massage. The H reflex is a method of recording alpha motor neuron excitability by direct stimulation of the Ia fibres in a peripheral nerve, and measuring the excitability in the alpha motor neurons of the segmental innervated muscle. These findings suggest that cutaneous afferents are not as important as mechanoreceptor afferent input in the modulation of muscle activity. This is further supported by the findings of a study by Murphy et al.,31 in which an anaesthetic cream was used on the skin and resulted in no significant difference in alpha motor neuron attenuation post manipulation between a group who had the cream applied and a group without.

Dishman et al.32 later questioned some of their own previous work. In this subsequent paper, the authors stated that the H-reflex technique is susceptible to the effects of pre-synaptic inhibition of the afferent arm of the reflex pathway. So, by choosing a technique that directly measured the effect of corticospinal inputs on the alpha motor neuron pool (transcranial magnetic stimulation), they were able to perform an experiment which showed a transient (20–60 s) increase in motor alpha neuron excitability post manipulation. This paper lends further support to the theory that spinal manipulation produces a brief activation of the motor alpha neuron leading to brief muscle contraction.

Keller and Colloca13 assessed changes in trunk muscle strength subsequent to manipulation, using an activator device. They demonstrated a significant increase in post-treatment MVC as compared to a sham manipulation and no intervention group, providing some evidence that spinal manipulation may alter the neurophysiological control of the paraspinal muscles.

Theories of how manipulation alters muscle tone

Inhibition

Indahl et al.34 studied the EMG reaction to porcine zygapophysial joint saline injections. The authors demonstrated that distension of the facet joint decreased muscle activation in the paraspinal muscles, and hypothesised that the mechanism for this was that stretch of the facet joint capsule caused excitation of an inhibitory interneuron, which inhibited alpha motor neuron activation. This provides a plausible theory for what might occur during spinal manipulation, if indeed the facet joint capsule is stretched by the mechanical distraction of the HVLAT.

Gamma gain

The early work of Denslow and Korr’s35–37 in the 1940s provided an evidential basis for Korr’s theory of the facilitated segment. The authors conducted primitive EMG studies and demonstrated an enhanced EMG response to a stimulus applied over a painful segment, and thus developed the theory that a painful segment had a facilitatory response and lowered threshold to stimuli. This has been supported more recently by Lehman et al.39 with a more methodically sound and more vigorously controlled study: their study also showed a decrease in EMG activity to a painful stimulus, post-HVLAT, but this did not occur at a non-painful control segment.

Korr’s theory of the facilitated segment was that an increase in gamma motor neuron activity reflexly increased the alpha motor neuron, and led to hypertonicity. Korr proposed that HVLAT increased joint mobility by producing a barrage of impulses which silenced the facilitated gamma motor neurons. This theory is contentious, as there is no clear evidence that there is facilitation of the alpha motor neuron.

Pain–spasm–pain

Travell et al.30 proposed a pain–muscle spasm–pain cycle in which accumulation of muscle metabolites in a static muscle increased the sensitivity of muscle spindles, via a reflex pathway. Chemosensitive nociceptors from group III and IV afferents are thought to have an excitatory effect on the efferent gamma motor neurons. This increases the muscle spindle sensitivity to stretch and increases the activation of the homonymous alpha motor neurons and then the cycle self perpetuates. It has been shown that if the nociceptors are artificially stimulated, there was an increase in fusimotor activation in the cat.40

However, Mense and Skepppur41 showed that muscle inflammation leads to short-term inhibition of the gamma motor neurons, and thus lowered muscle spindle threshold, which would contradict the pain–spasm–pain theory. Furthermore, Kang et al.42 performed a study injecting irritants into cat muscle which produced no alteration in muscle activity, thereby suggesting that there is no effect on fusimotor control. It is also of some debate as to whether there is
an increase in alpha motor neuron activity in subjects with back pain, which also brings into question the likelihood of this theory.

**Post activation depression**

Another theory for a reflex reduction in muscle tone following HVLAT is post activation depression. This is a short-lived (12–15 ms) motor neuron attenuation following reflex muscle contraction, due to depletion of neurotransmitter at the 1α-α motor neuron synapse. As a short-lived response, this phenomenon is unlikely to explain any of the longer-lasting effects of manipulation, but might give an indication of reflex activity in the spinal cord.

**Neurophysiological**

**Hypoalgesic effects of spinal manipulation**

There are some studies providing evidence that spinal manipulation has a hypoalgesic effect.\(^{47}\) Manipulation may alter pain perception by one of three mechanisms: modulation of the pain gate mechanism, activation of descending pain mechanisms, or by stimulating the release of neurotransmitters.

**Pain gate mechanism**

Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage;\(^{44}\) our understanding of pain was furthered in the 1960s by Melzack and Wall’s\(^{45}\) theory of the pain gate mechanism. They described the dorsal horn of the spinal cord as having a gate-like mechanism which modulates the central transmission of afferent nociceptive input. Nociceptive afferents from small diameter A\(\beta\) and C fibres tend to open this gate, and non-nociceptive large diameter A\(\gamma\) fibres (from joint capsule mechanoreceptor, secondary muscle spindle afferents, and cutaneous mechanoreceptors) tend to close the gate to the central transmission of pain. This modulation takes place in the lamina of the dorsal horn. Simplistically, A\(\beta\) afferent enter lamina II and V, stimulating an inhibitory interneuron in lamina II (which connects to lamina V); A\(\gamma\) and C fibres enter lamina V. Consequently, the central transmission of pain is a balance between the influences of these opposing stimuli.\(^{44}\) HVLAT may modulate the pain gate mechanism in the dorsal horn by producing a barrage of non-nociceptive input from large diameter myelinated A\(\beta\) afferents from muscle spindles and facet joint mechanoreceptors.\(^{46}\)

**Descending pain mechanism**

Descending pathways also influence pain perception. There is a specific part of the brain, the periaqueductal gray (PAG) grey matter surrounding the 3rd ventricle, which when stimulated produces profound analgesia via the descending PAG pathways.\(^{47}\) Stimulation of the dorsal PAG (dPAG) in the brain produces selective analgesia to mechano-nociception, whereas temperature nociception is modulated via the ventral PAG (vPAG). It is also known that sympatho-excitation results from stimulation of the dPAG, in contrast to sympatho-inhibition which occurs as a result of stimulating vPAG.\(^{46}\)

Activation of the descending dPAG is a possible mechanism for the antinociceptive effects of spinal manipulation and as such is receiving some recent attention in the literature. Sterling et al.\(^{49}\) measured changes in pain and sympathetic outflow by comparing a C5/6 HVLAT to a sham manipulation (manual contact but with no movement). The authors demonstrated HVLAT produced mechanical hypoalgesia, measured by an increase in pain pressure threshold, and increased sympathetic outflow, measured by decreased blood flow, decreased skin temperature, and increased skin conductance. However, there was no alteration to thermal pain thresholds. Given such selective mechanical anti-nociception and sympatho-excitation, this supports the theory that the mechanism of effect is due to activation of the dPAG descending pain mechanism. Vincenzino et al.\(^{50,51}\) conducted similar experiments on subjects with epicondylitis and showed again that cervical spine HVLAT lead to selective analgesia to mechanical stimulus and sympatho-excitation, adding further weight to the argument that spinal manipulation may influence the perception of pain by activation of the descending dPAG.

**Neurotransmitters**

Several neurotransmitters have been found to be important in pain sensation and substance P is one which has been widely studied; it is released in the dorsal horn of the spinal cord by C fibres and facilitates the central transmission of nociceptive input.\(^{44}\) It is thought that \(\beta\)-endorphins exert their anti-nociceptive influence by decreasing the effectiveness of substance P in the dorsal horn, thereby decreasing afferent nociceptive input to higher centres.\(^{44}\) The effect of spinal manipulation on the release of \(\beta\)-endorphins has been studied by Vernon et al.,\(^{52}\) who showed an increase in \(\beta\)-endorphins in a group receiving HVLAT compared to a group receiving a sham manipulation (a rotational mobilisation). Unfortunately, there has been no further work on this mechanism, except for a study by Christian et al.\(^{53}\) who showed no significant difference between a manipulation and control group in release of \(\beta\)-endorphins. However, Wright\(^{54}\) has highlighted that the assay of Christian et al.\(^{53}\) was not sensitive enough to detect baseline endorphin levels.

Placebo effect

Whilst the physiological mechanism of HVLAT is not fully understood, it is clear that as with any intervention there is likely to be a placebo effect. Indeed, it has been indicated that as manipulative therapy has a significant placebo effect, sham controlled trials are essential to demonstrate efficacy beyond the placebo effect; however, even if manipulation represents a powerful placebo, this might still be useful in clinical practice. Both the patient and practitioner are mainly concerned with a clinical improvement, and a placebo effect may still be valid, as long as there is no significant risk from the treatment. It is important that the role of placebo treatment should not be underestimated, and the impact of patient contact with health care professionals must be considered as a potentially positive element of a treatment plan.55

DISCUSSION

Numerous authors have investigated the effects of spinal manipulative treatment for low back pain, helping to provide some insight into the underlying physiological mechanisms. There is some evidence to support the theory that HVLAT evokes spinal stretch reflexes, and that there is a brief muscle contraction possibly followed by a period of reduced muscle activity. This potentially important finding warrants further research as it would provide a mechanism for explaining some of the local muscle responses. It also provides support of the existence of supraspinal influences. Reflex activation of alpha motor neurons may lead to a resetting of muscle activity and lead to a period of reduced hypertonicity, although as yet the findings have not been conclusive. There is some reasonable evidence that there is a gapping of the facet joints during manipulation, although the clinical and therapeutic significance of this effect is not clear. There is also considerable evidence for the anti-nociceptive treatment effects of HVLAT and this would have obvious benefit to the patient.

There is some evidence in the literature for each of these three of the theories for the action of manipulative treatment. Indeed, it may be that spinal manipulation exerts its physiological influence by a combination of these effects. There is also likely to be a placebo action56 and this will have a contributory effect to the therapeutic benefit of HVLAT. However, many of the studies described are flawed by their poor methodological details, including small sample sizes, and lack of control groups. Only further methodologically sound experimentation will advance our understanding of the physiological effects of spinal manipulation.

CONCLUSIONS

Many current studies are considering the significance of the patient–practitioner relationship and the potential relevance of this intervention to the outcome of the therapeutic encounter. However, it is still important that further scientific research is carried out in order to complete the understanding of the basic neurophysiological mechanism of HVLAT. As there is no clear paradigm for the mechanisms of spinal manipulation, it is important that this area has further high quality research in order to understand how manipulative treatments may produce their reported benefits.

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