



## Masterclass

# Why do spinal manipulation techniques take the form they do? Towards a general model of spinal manipulation

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## ABSTRACT

For centuries, techniques used to manipulate joints in the spine have been passed down from one generation of manipulators to the next. Today, spinal manipulation is in the curious position that positive clinical effects have now been demonstrated, yet the theoretical base underpinning every aspect of its use is still underdeveloped. An important question is posed in this masterclass: why do spinal manipulation techniques take the form they do? From the available literature, two factors appear to provide an answer: 1. *Action of a force upon vertebrae*. Any 'direct' spinal manipulation technique requires that the patient be orientated in such a way that force is applied perpendicular to the overlying skin surface so as to act upon the vertebrae beneath. If the vertebral motion produced by 'directly' applied force is insufficient to produce the desired effect (e.g. cavitation), then force must be applied 'indirectly', often through remote body segments such as the head, thorax, abdomen, pelvis, and extremities. 2. *Spinal segment morphology*. A new hypothesis is presented. Spinal manipulation techniques exploit the morphology of vertebrae by inducing rotation at a spinal segment, about an axis that is always parallel to the articular surfaces of the constituent zygapophysial joints. In doing so, the articular surfaces of one zygapophysial joint appose to the point of contact, resulting in migration of the axis of rotation towards these contacting surfaces, and in turn this facilitates gapping of the other (target) zygapophysial joint. Other variations in the form of spinal manipulation techniques are likely to depend upon the personal style and individual choices of the practitioner.

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## 1. Introduction

For centuries, techniques used to manipulate joints in the spine have been passed down from one generation of manipulators to the next (Anderson, 1992; Harris, 1993; Bartol, 1995; Wiese and Callender, 2005). Once the domain of laymen, spinal manipulation is now, for the most part, provided by organised professional groups. Whilst these techniques have no doubt evolved over time, their progression has largely been empirical; their form today is most likely a culmination of demonstration, imitation, and iterative adaptation. This is in contrast to most modern healthcare interventions, such as pharmaceuticals or medical devices, which are usually developed upwards from a theoretical base.

Much has been written about joint manipulation in recent years, and the volume of research has grown steeply during this period. In fact, for low back pain, there are now more randomised controlled trials evaluating spinal manipulation than any other intervention

(Bronfort et al., 2008). In contrast, basic science studies are relatively uncommon. Hence, spinal manipulation is in the curious position that some positive clinical effects have now been demonstrated (Assendelft et al., 2003; Bronfort et al., 2004, 2008; Gross et al., 2004), yet the theoretical base underpinning every aspect of its use is still underdeveloped (Cramer et al., 2006).

A careful exposition of currently available data (Evans and Lucas, submitted for publication) has provided a proposed list of features that are necessary and collectively sufficient for the occurrence of (and which may be used to define) manipulation of any individual joint (Table 1). Hence, something of a general model, incorporating both the physical action of the practitioner and mechanical response of the recipient, may be derived from these features.

For a general model of manipulation to be valid, it must be representative of manipulation in all synovial joints of the body. Indeed, spinal manipulation is simply manipulation of synovial joints in the vertebral column. However, the motion of an entire spinal motion segment (and the synovial joints within) is usually much more complex than motion of an independent, peripheral synovial joint. Consequently, whilst the general model formed from the above features may well be valid, further explanation is

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**Table 1**

Proposed necessary features of joint manipulation (from Evans and Lucas, submitted for publication).

**Action (that which the practitioner does to the recipient)**

A force is applied to the recipient

The line of action of this force is perpendicular to the articular surface of the affected joint

**Mechanical response (that which occurs within the recipient)**

The applied force creates motion at a joint

This joint motion includes articular surface separation

Cavitation occurs within the affected joint

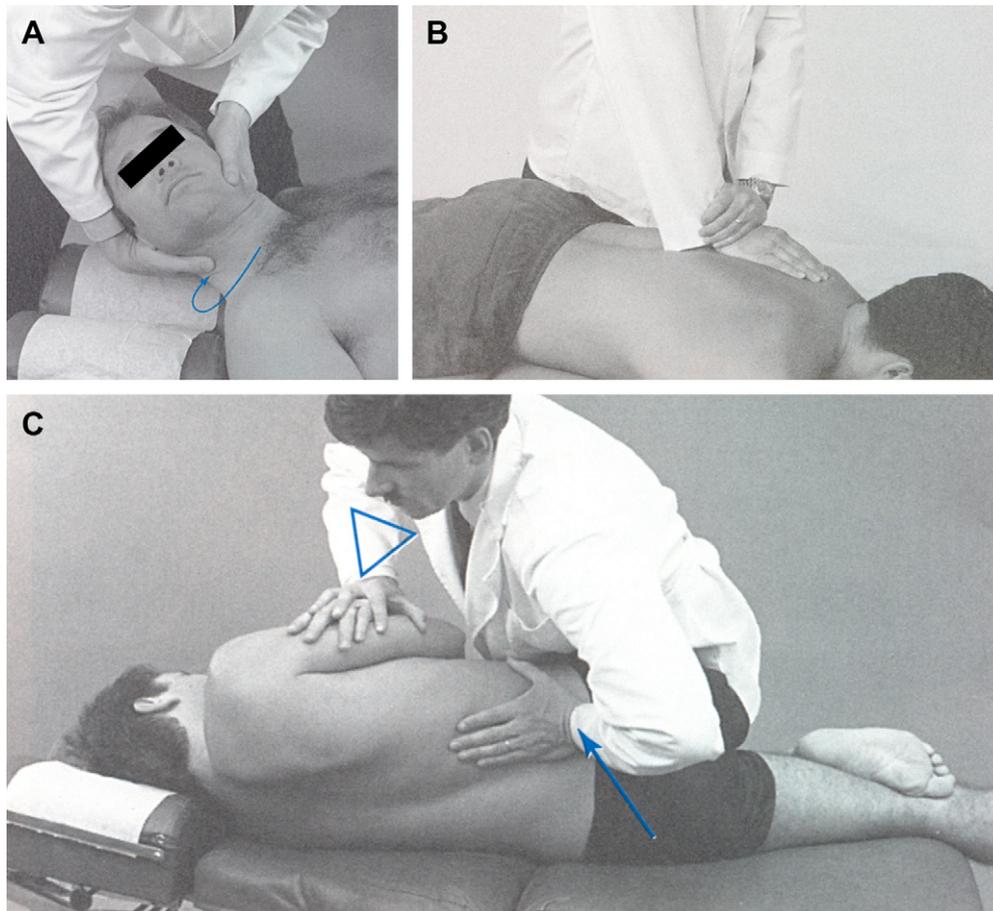
required to provide an understanding of how these features operate during manipulation of joints in the spine.

For this purpose, a different question can be asked: why do spinal manipulation techniques take the form they do? Indeed, if all manipulation techniques encompass these fundamental features, additional factors must give rise to the forms of the techniques that are consistently applied to the various spinal regions (Fig. 1). Despite displaying clear similarities, these techniques are still usually taught as an eclectic collection, rather than being unified by a general theory, or model, that explains their form. This paper examines such factors and presents a first attempt at constructing such a general model from the available scientific data.

**2. Discussion****2.1. Action of a force upon vertebrae**

At a very basic level, spinal manipulation requires the action of an externally applied force upon one or both vertebrae of a chosen ('target') spinal motion segment. Unlike bones in the non-axial skeleton, vertebrae are relatively inaccessible. Indeed, with the exception of the cervical spine, only the most posterior features of vertebrae are close to the skin surface. Fig. 1A illustrates how some cervical manipulation techniques take advantage of the relative accessibility of the cervical spine by utilising two contact points. To apply forces 'directly' to vertebrae in the thoracic and lumbar regions, there is no non-invasive option other than doing so through the posterior overlying skin.

Forces applied at the skin surface in any spinal region must usually pass through substantial superficial tissue, which readily deforms as a result (McGregor et al., 2001; Powers et al., 2003; Kulig et al., 2004). Skin itself is a non-linear viscoelastic tissue, which demonstrates directionally dependent mechanical properties (Alexander and Cook, 1977; Stark, 1977; Daly, 1982; Reihner et al., 1995). Furthermore, there is negligible friction between the skin and the connective tissues that lie superficial to the spine (Bereznick et al., 2002), irrespective of whether force is applied through an irregular shaped contact (such as a hand) or not. The implications of these basic science data for the form of spinal manipulation techniques are important: only when applied



**Fig. 1.** Typical forms of spinal manipulation techniques. A. Supine 'rotatory' mid-cervical manipulation. B. Prone unilateral 'posterior-anterior' lower thoracic manipulation. C. Side-posture 'rotational' lumbar manipulation. All figures reproduced from Peterson and Bergmann (2002).

perpendicular (at 90°) to the skin surface is force likely to act significantly on internal structures (see also Kawchuk and Perle, 2009), and a proportion of any applied force is always likely to be dissipated by superficial tissues.

The results from these laboratory studies are supported by data from studies of actual spinal manipulation. Three-dimensional contact forces, applied by a clinician to the skin surface during cervical, thoracic and lumbosacral manipulation, have been directly measured using a small hand-held force sensor (van Zoest et al., 2002; van Zoest and Gosselin, 2003). Technically, the sensor measured the reaction force from the skin upon the device, as force was applied to the skin (with the aim of acting on tissues beneath). Hence, if friction between the skin and the underlying connective tissues was negligible, little reaction force parallel to the skin surface would be applied to the device. Predictably, the results from these studies confirmed that the only significant component of force applied to the skin was that which was perpendicular to the skin surface.

In a study of lumbar spine manipulation, Bereznick (2005) demonstrated that forces applied by hand contact towards lumbar vertebrae, through the posterior overlying skin (Fig. 1C), did not significantly contribute to the production of cavitation (which manifests as the 'audible sound', mentioned in Table 1); neither the magnitude or location of applied force was as important as the magnitude of rotational torque in the transverse plane. In order to create this rotational torque, the majority of force had to be applied 'indirectly' to the vertebrae, via the pelvis and thigh of the recipient.

Collectively, these data mean that any 'direct' spinal manipulation technique requires that the patient be orientated in such a way that force is applied perpendicular to the overlying skin surface so as to act upon the vertebrae beneath. If the vertebral motion produced by 'directly' applied force is insufficient to produce the desired effect (e.g. cavitation), then force must be applied 'indirectly', often through remote body segments such as the head, thorax, abdomen, pelvis, and extremities. Equally, if the body weight of the clinician is to be fully exploited during a technique, then the patient must be orientated in such a way that the point of contact at the skin surface is horizontal and that the clinicians' centre of mass is aligned directly above.

Fig. 2 depicts the typical time histories of forces applied perpendicular to the skin surface of a patient during spinal manipulation (Herzog, 2000; Evans and Breen, 2006). That this temporal kinetic profile is similar with manipulation techniques used at all spinal levels is notable given the anatomical variation between spinal regions.

## 2.2. Spinal segment morphology

To be consistent with features common to manipulation in other synovial joints (described in Table 1), the motion induced in a spinal

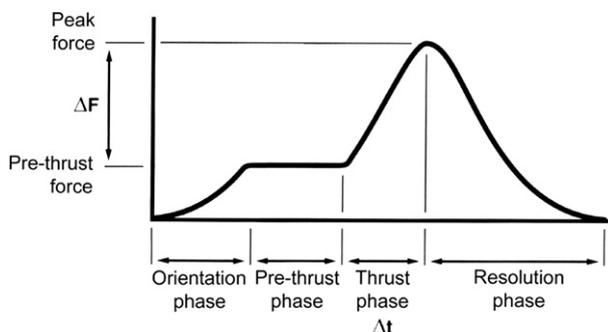


Fig. 2. Typical pattern of applied forces during spinal manipulation. A similar force profile occurs during manipulation of joints in all spinal regions. Figure reproduced from Evans and Breen (2006), originally modified from Herzog (2000).

segment during spinal manipulation must result in the separation of the articular surfaces (gapping) of one, or both, of the posterior synovial (zygapophysial, atlantoaxial, occipitoatlantal, or lumbosacral) joints.

With regard to a single zygapophysial joint, articular surface gapping requires translation of one superior articular process of the lower (caudad) vertebra in a direction opposite to that of the articulating inferior articular process of the upper (cephalad) vertebra of that segment. In contrast, symmetrical gapping of both zygapophysial joints within a single segment would require an anterior translation of the entire caudad vertebra relative to its cephalad neighbour. Importantly, several studies have shown that significant bilateral zygapophysial joint gapping usually only follows failure (injury) of restraining tissues in that segment (Levine et al., 1988; Tohme-Noun et al., 2003; Carrino et al., 2006). Consequently, it is likely only to be possible to gap one zygapophysial joint in any single spinal segment without exceeding tissue failure limits. As a result, the required motion of the target spinal segment during spinal manipulation will always be asymmetrical (a criterion that excludes motion purely in the sagittal plane), which is consistent with observation (Fig. 1). Accordingly, the manipulation force must be applied along a line of action such that the existing morphology of the target spinal segment is exploited to induce separation of the articular surfaces of one (target) zygapophysial joint. There are several hypotheses that attempt to explain how this transpires.

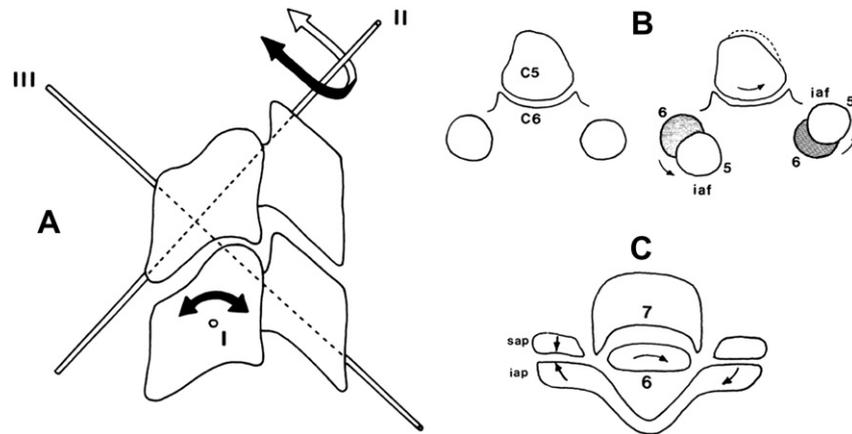
### Hypothesis 1. Segmental motion that opposes coupling.

Several authors have proposed that the basis of spinal manipulation kinematics is that the induced motion of the target segment directly opposes normal segmental coupling (Nyberg, 1993; Gibbons and Tehan, 2001; McCarthy, 2001). An example where this is clearly evident is in the cervical spine.

It is well known that transverse rotation in typical cervical segments (C3–C7) is accompanied by ipsilateral lateral flexion, and vice versa (Lysell, 1969; Penning and Wilmlink, 1987; White and Panjabi, 1990; Cook et al., 2006). Of the various elements of a spinal segment, the geometry of zygapophysial joints has most bearing on the kinematic behaviour of that segment (Malmivaara et al., 1987; Singer et al., 1988; Panjabi et al., 1993; Bogduk and Mercer, 2000; König and Vitzthum, 2001; Pal et al., 2001). Hence, the coupling pattern seen in typical cervical segments arises primarily because the articular surfaces of the zygapophysial joints are orientated some 40° ventrad to the frontal plane (Penning and Wilmlink, 1987; Milne, 1991). This means that unilateral (non-sagittal) rotation occurs between neighbouring cervical vertebrae about an oblique axis that lies in the sagittal plane, passing upwards and backwards through the front of the disc and through the posterior part of the moving vertebral body, perpendicular to the surfaces of the zygapophysial joints (Milne, 1991). This is illustrated in Fig. 3A.

As a further upshot of this configuration, isolated lateral flexion at a cervical motion segment is not possible as rotation about an axis parallel to the plane of the zygapophysial joints is precluded by the impaction of the joints (Bogduk and Mercer, 2000). Therefore, of those described by the three 'cardinal' planes, only two natural forms of motion are permitted by the morphology of a typical cervical segment; sagittal rotation and a combined 'transverse and frontal' rotation about an axis perpendicular to the plane of the zygapophysial joints (Fig. 3B).

A variety of cervical spine manipulation techniques are available (Kawchuk and Herzog, 1993). Even so, irrespective of the minutiae variation employed in different cervical spine manipulation techniques, the fundamental kinematics are always the same. Studies that have measured global cervical spine kinematics during cervical manipulation consistently demonstrate transverse rotation



**Fig. 3.** A. The three mutually perpendicular axes of rotation in typical cervical motion segments. B. Rotation of a typical cervical segment (C5–C6) occurring about axis II. The figure shows a cross-section of the segment, viewed from above, along the same axis. Rotation of the C5 vertebra about this axis allows its inferior articular facets (iaf) to freely glide across the superior articular facets of C6. C. Rotation to the left of a typical cervical segment occurring about axis III. The figure shows a cross-section of the segment, viewed from above, along the same axis. Rotation to the left of the C6 vertebra about this axis results in the immediate impaction of its right inferior articular process (iap), en face, into the superior articular process (sap) of C7, which precludes further rotation of C6 about this axis. All figures modified from Bogduk and Mercer (2003).

accompanied by contralateral lateral flexion (Triano and Schultz, 1994; Klein et al., 2003; Ngan et al., 2005). Despite not revealing exactly what happens at individual segments, this motion pattern is in direct contrast to normal coupling patterns and, in effect, equates to forced rotation about the 'blocked' axis of a typical cervical segment (axis III in Fig. 3). A typical mid-cervical 'rotatory' manipulation that clearly demonstrates this motion pattern is shown in Fig. 1A.

Although rather elegant, this hypothesis falls down when other spinal regions are considered. Recent studies have shown that both thoracic and lumbar spinal segments do not demonstrate consistent coupling behaviour (Legaspi and Edmond, 2007; Sizer et al., 2007). However, a reinterpretation of the kinematics of cervical spine segments offers an alternative hypothesis that can be tested in other spinal regions: the arrangement of restraints for every spinal segment results in rotation that is 'blocked' about a particular axis, and this is exploited by manipulation techniques.

*Hypothesis 2. Rotation about a 'blocked' axis, parallel to zygapophysial joint surfaces.*

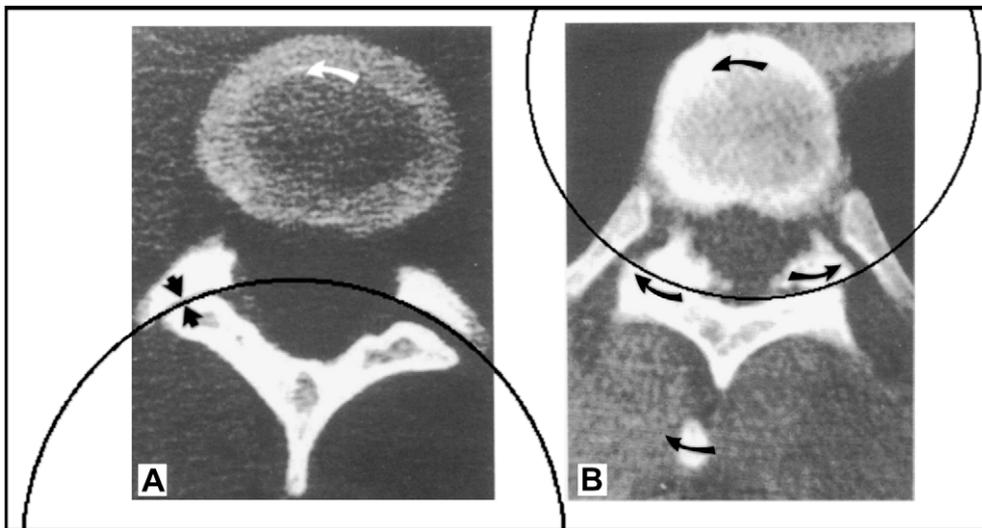
A spinal segment has two rather obvious functionally distinct sections; the anterior and posterior elements. In the absence of the posterior elements (principally the zygapophysial joints), the spine would be a relatively simple and easily deformable structure, consisting mainly of a column of vertebral bodies and intervertebral discs, surrounded by anterior and posterior longitudinal ligaments. Hence, motion of these segments would be entirely a function of these isolated anterior elements and would be available, to some extent, in all six degrees of freedom: rotation about and translation along three mutually perpendicular axes (White and Panjabi, 1971; Adams and Hutton, 1983; McGlashen et al., 1987; Stokes, 1988; Abumi et al., 1990; Nägerl et al., 1990; Spenciner et al., 2006).

Conversely, in the absence of the anterior elements (above all, the intervertebral disc), the motion of each spinal segment would be entirely a function of its posterior elements, principally the superior and inferior articular processes and the zygapophysial joints that they form. The orientation and morphology of the zygapophysial joints vary greatly, usually predictably, according to spinal level. Typical lumbar zygapophysial joints (L1–L5) are almost planar in nature and their articular facets are approximately aligned to the sagittal plane (Fig. 4A). As such, the geometry of these

articular surfaces when viewed in the transverse plane (effectively a cross-section of the zygapophysial joints) can be approximated by a circle, drawn perpendicular to the articular surfaces, whose circumference passes between the articular surfaces of each joint (van Schaik et al., 1997). Hence, in the absence of anterior elements, the centre of this circle will effectively represent a 'natural' axis for rotation of the isolated posterior elements in the transverse plane; the axis being parallel to the plane of the zygapophysial joint surfaces (Fig. 4A). Uninterrupted, the surfaces of each zygapophysial joint would freely glide over one another on the circumference of this circle, limited chiefly by the restraint provided by the joint capsule and surrounding ligaments, which when intact (Zdeblick et al., 1993; Sim et al., 2001) ensure the joint surfaces do not 'slide off' one another. In reality, the surfaces of zygapophysial joints are not perfectly congruent and consequently the precise location of this axis would vary slightly during transverse rotation (Kubein-Meesenburg et al., 1991; Nägerl et al., 1992), but the use of a 'facet orientation circle' (van Schaik et al., 1997) suffices for the present discussion.

When anterior and posterior elements are combined, as in a complete spinal segment, something of a mechanical 'tussle' ensues between the two elements, and motion is constrained as a result (Berkson, 1977; Nägerl et al., 1992; Thompson et al., 2003; Mansour et al., 2004). In lumbar spinal segments, an immediate upshot of this complete articular arrangement (the 'articular triad') is an anterior migration of the axis of transverse rotation to a location within the posterior third of the annulus fibrosus of the intervertebral disc (Cossette et al., 1971) (Fig. 5A), where the axis of minimal torsional stiffness lies (Adams and Hutton, 1981). As a result, the range of lumbar transverse rotation is very limited (approximately 1–2° in each direction), being effectively 'blocked' by the articular surfaces of the ipsilateral zygapophysial joint approximating to the point of contact (Singer et al., 1989; Singer and Giles, 1990; Shirazi-Adl, 1994) (Figs. 4A and 5B).

If transverse rotation in lumbar spinal segments is forced beyond this physiological range, compressive forces are generated on the impacted surfaces of the ipsilateral zygapophysial joint (Adams and Hutton, 1981) and rotation will occur about a new axis of transverse rotation, parallel to the previous one, but now located within the impacted joint (Nägerl et al., 1992; Mansour et al., 2004). Effectively, the axis of transverse rotation is forced to migrate to where the impacted surfaces of this joint meet. As a result, the



**Fig. 4.** Transverse rotation in (A) lumbar and (B) thoracic spinal segments, viewed in the transverse plane. The axis of rotation is perpendicular to the surfaces of the zygapophysial joints in both cases and a 'facet orientation circle', which represents the cross-sectional geometry of a pair of zygapophysial joints in the transverse plane, is superimposed on each image. The centre of this circle clearly lies posterior to the intervertebral disc in the lumbar segment, whereas it lies within the intervertebral disc in the thoracic segment. Modified, with permission, from Singer (1994).

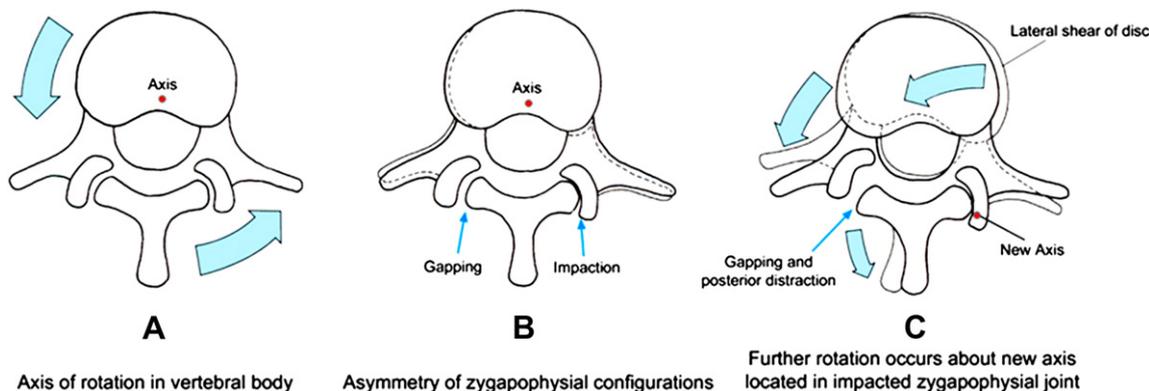
surfaces of the contralateral zygapophysial joint separate (Singer et al., 1989; Fazey et al., 2006), with little resistance from the joint capsule and surrounding ligaments (Adams and Hutton, 1981). This can clearly be seen in Fig. 4A. Intriguingly, this is precisely what appears to occur during lumbar spine manipulation (Singer and Giles, 1990; Cramer et al., 2000, 2002) (Fig. 1C).

There is evidence from other spinal regions to support the hypothesis that forced rotation about a 'blocked' axis of rotation, parallel to the articular surfaces of the zygapophysial joints, is associated with joint gapping. The coupling patterns of cervical segments are obscured when the conventional 'cardinal' axes reference framework is used to describe the motion of spinal segments (Fig. 6). However, Fig. 3A clearly illustrated that rotation about an axis parallel to the zygapophysial joint surfaces is blocked in typical cervical segments (C3–C7). Furthermore, Fig. 6 shows that rotation about one cardinal axis is blocked also in atypical cervical (C0–C2) and lumbosacral segments. Closer scrutiny reveals that each of these blocked axes is parallel to the articular surfaces of the respective posterior joints (Werne, 1958; White and Panjabi, 1990; Taylor and Twomey, 1994; Worth, 1994; Bogduk and Mercer, 2000; Bogduk, 2005).

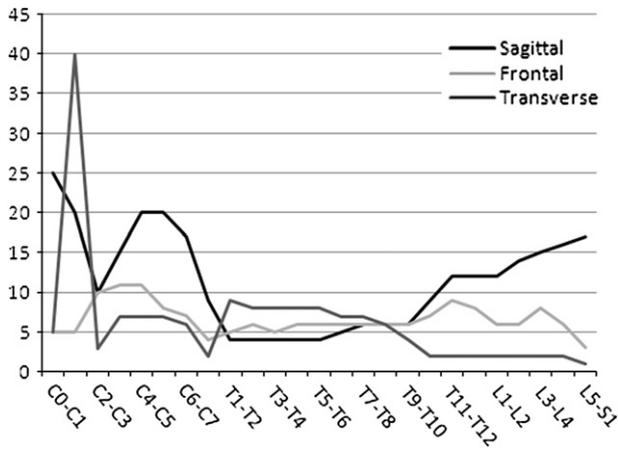
This hypothesis clearly performs well. That is, until the thoracic spine is considered. With frontally orientated zygapophysial joints, the axis parallel to the zygapophysial joint surfaces corresponds to that of transverse rotation. However, when considering anterior and posterior elements separately, the centre of transverse rotation relating to both elements lies fairly close to the location of minimal torsion of the intervertebral disc synarthrosis (Nägerl et al., 1990; Molnár et al., 2006). Consequently, transverse rotation is not naturally blocked in thoracic segments (Fig. 4B). In fact, no axis of segmental rotation is naturally blocked, even outside of the cardinal reference system. Thus, the hypothesis that gapping of a zygapophysial joint within a complete spinal segment is always a result of forced rotation about a naturally blocked axis appears to be insufficient.

*Hypothesis 3. Migration of the axis of rotation to the contralateral zygapophysial joint.*

In general, rotation of a complete spinal segment is available about an axis that is perpendicular to the plane of the zygapophysial joint surfaces. In contrast, if a naturally blocked axis exists, it lies parallel to the plane of the zygapophysial joint



**Fig. 5.** Transverse plane cross-sections of a typical lumbar segment during stages of transverse rotation. The figure depicts the configuration of the zygapophysial joints viewed along the axis of transverse rotation, which is parallel to the articular surfaces of the zygapophysial joints. Reproduced from Bogduk (2005).



**Fig. 6.** Superimposed representative angles of sagittal (flexion–extension), frontal (lateral bending), and transverse (horizontal) rotation for all spinal segments. As these ranges of motion were produced from cadavers, they are likely to be representative of passive ranges of motion. Based on data from White and Panjabi (1990).

surfaces. In all spinal regions examined so far, spinal manipulation techniques have been seen to exploit these naturally blocked axes, orientating the target segment such that the line of action of the applied force is perpendicular to the articular surfaces of the target joint; a feature observed as common to all forms of manipulation (Table 1).

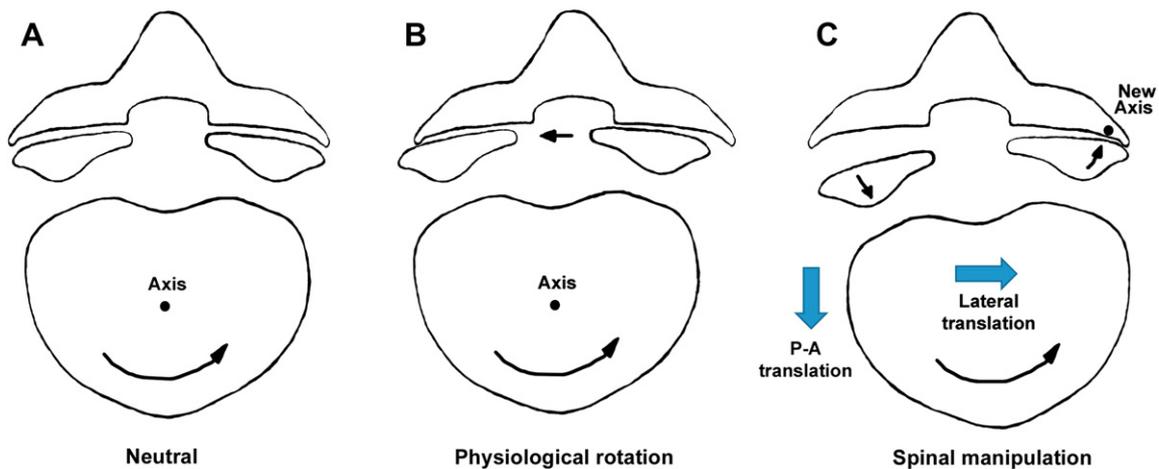
Thoracic spinal segments differ from those in other spinal regions in that, particularly when isolated from the ribs, rotation about an axis parallel to the articular surfaces of zygapophysial joints (transverse rotation) is not naturally blocked. Instead, the frontally orientated zygapophysial joint surfaces are free to glide in all directions and allow transverse rotation, which is largely unopposed by the intervertebral disc (Fig. 4B). A modification of Hypothesis 2 is therefore required if a successful general model of spinal manipulation is to be attained.

In all spinal regions examined so far, a consistent relationship has existed between the two zygapophysial joints of the target segment; target joint gapping was always accompanied by contralateral ‘non-target’ joint surface contact. In the thoracic spine

this presents a problem because no naturally occurring axis of rotation is blocked by impacted zygapophysial joint surfaces, even when departing from the cardinal reference system. Hence, if this relationship is to occur during manipulation in thoracic segments, the natural configuration of these segments must be changed in some additional way.

As mentioned above, the articular surfaces of zygapophysial joints in typical thoracic segments (T4–T10) are orientated close to the frontal plane. Separation of the surfaces of one of these zygapophysial joints therefore requires a relative anterior translation of the ipsilateral superior articular process of the caudad vertebra. As a result, force can be applied directly over the caudad vertebra in a posterior–anterior direction, perpendicular to the skin surface, without modifying the resting configuration of a patient in prone lying (Fig. 1B).

Only one study with rigorous methodology (Gál et al., 1994, 1995) has provided accurate three-dimensional kinematic data for both absolute and relative vertebral movements during manipulation of the thoracic spine. This study measured vertebral motion using bone pins embedded in the T10, T11 and T12 (atypical thoracic) vertebrae of unembalmed post-rigor human cadavers while a prone unilateral posterior–anterior manipulation was performed using a reinforced hypothenar contact (see Fig. 1B). Several manipulation ‘trials’ were recorded in the study and only one single cavitation event at T11–T12 was recorded. The kinematic data of all manipulation trials were compared and consistently demonstrated simultaneous transverse and sagittal rotations, combined with a posterior–anterior translation. However, these data also showed that a significantly greater lateral translation of the inferior vertebra (T11), away from the manipulating hand, was associated with the single occurrence of cavitation (Gál et al., 1995). Although these results need verification, because they are based on only one case and because of the variability in the atypical, lower thoracic spine orientation and morphology (Singer et al., 1988), it is tantalising to conclude that this additional lateral translation effectively migrated the axis of transverse rotation towards the contralateral zygapophysial joint. Consequently, the previously free transverse rotation would become blocked due to the now impacted contralateral zygapophysial joint surfaces, and further, forced rotation results in gapping of the other (target) joint (Fig. 7).



**Fig. 7.** Transverse plane cross-sections of a typical thoracic segment during: A. Neutral configuration. B. ‘Physiological’ transverse rotation, which occurs about an axis parallel to the articular surfaces of the zygapophysial joints. C. The predicted motion that occurs during manipulation at a typical thoracic segment. Separation of the articular surfaces of one zygapophysial joint results from simultaneous sagittal and transverse rotations, combined with posterior–anterior and lateral translation of the caudad vertebra relative to its cephalad neighbour.

### 3. Conclusions

A question was posed at the beginning of this paper: why do spinal manipulation techniques take the form they do? From the available literature, two factors appear to provide an answer: how an applied force is able to act upon vertebrae of a target spinal segment, and the morphology of those vertebrae.

Any 'direct' spinal manipulation technique requires that the patient be orientated in such a way that force is applied perpendicular to the overlying skin surface so as to act upon the vertebrae beneath. If the vertebral motion produced by 'directly' applied force is insufficient to produce the desired effect (e.g. cavitation), then force must be applied 'indirectly', often through remote body segments such as the head, thorax, abdomen, pelvis and extremities.

The available data from biomechanical studies so far support the hypothesis that spinal manipulation techniques exploit the morphology of vertebrae by inducing rotation at a spinal segment, about an axis that is always parallel to the articular surfaces of the constituent zygapophysial joints. In doing so, the articular surfaces of one zygapophysial joint appose to the point of contact, resulting in migration of the axis of rotation towards these contacting surfaces, and in turn this facilitates gapping of the other (target) zygapophysial joint. There is sufficient evidence to suggest that the alternative hypotheses described previously are insufficient to describe the segmental kinematics occurring during all spinal manipulation techniques and should therefore be rejected. Importantly, the retained hypothesis is consistent with all previously identified necessary features of joint manipulation, listed in [Table 1](#).

Other variations in the form of spinal manipulation techniques are likely to depend upon the personal style and individual choices of the practitioner. Indeed, a general model of spinal manipulation requires the assumption of equivalence of techniques; if successfully applied, any valid spinal manipulation technique should produce the same effect on a target joint as any other. For example, spinal manipulation techniques have historically been divided into direct (or 'short-lever') or indirect ('long-lever') techniques. The former involves the application of force directly over the target segment, whereas during the latter force is delivered to the target segment through its contiguous neighbours, and even from remote body segments such as the head, thorax, abdomen, pelvis and extremities. In both classes of technique, there will be some deformation of both superficial and restraining tissues. The above discussion imposes clear limiting conditions on the segmental motion likely to take place during any spinal manipulation technique. Hence, any distinction between 'long-lever' and 'short-lever' techniques appears to be arbitrary as they will result in very similar motion of the affected spinal segment.

This discussion is based on available basic science data. As such, any conclusions drawn are limited by the relatively small volume of these data and must therefore be considered tentative. Further studies are sorely needed, particularly *in vivo* studies of cervical and thoracic manipulation, where the influence of all restraining tissues (including the ribs and costal articulations) can be clearly observed. Hopefully then, we will move closer to possessing a valid general model of spinal manipulation.

### 4. Clinical summary

- Spinal manipulation techniques have been passed from one generation of manipulators to the next as an eclectic collection, rather than being unified by a general model.

- Such a general model would aid in the teaching and execution of these techniques, and provide insight into their likely safety and mechanisms of action.
- The material presented in this masterclass is written as a first attempt at constructing such a general model from available scientific data.
- Manual therapists should find this masterclass useful when learning spinal manipulation techniques, especially when anatomical models are used as teaching aids.

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