

Loads in the lumbar spine during traction therapy

Raymond YW Lee¹ and John H Evans²

¹The Hong Kong Polytechnic University ²Queensland University of Technology

The purpose of the present study was to determine the loads acting on the lumbar spine when traction therapy was given in the Fowler's position. The study had two parts: a theoretical analysis which showed that traction produced a flexion moment on the spine as well as axial distraction; and an experimental study which measured the flexion moment induced by the adoption of the Fowler's position. The Fowler's position is clinically essential in that it flexes the spine and takes up the slack of the posterior tissues before the traction force is applied. Hence the axial tension and flexion moment generated by the traction force are more effective in stretching the posterior tissues. The angle of pull on the traction harness influences the friction between the body and the couch. However, this consideration is not necessary if a split traction table is used. The mechanical effects of traction are compared with those produced by postero-anterior mobilisation. The relative magnitude and direction of loads produced, and their variation with segmental level should be considered by therapists when choosing a technique for treating low back pain. [Lee RYW and Evans JH (2001): Loads in the lumbar spine during traction therapy. *Australian Journal of Physiotherapy* 47: 102-108]

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Introduction

Lumbar traction has been used for the treatment of low back pain since the time of Hippocrates. Historically, it had also been used in the management of neurological conditions (Shterenshis 1997). Its widespread current use suggests some degree of success, although the outcome of only a few clinical trials has shown traction therapy to be beneficial (Mathews and Hickling 1975, Mathews et al 1988).

Lumbar traction can be applied in a variety of ways, with the patient in a range of postures (Maitland 1986). The traction force may be sustained or intermittent, and may be applied manually or by machines. There is no consensus on the choice or indications of the various forms of traction therapy, but it appears that intermittent motorised traction with the patient in the Fowler's position (ie supine with the hips and knees flexed, and the lower legs supported on a stool) is most frequently used (Maitland 1986).

The earliest study that examined the mechanical effects of lumbar traction was that of Judovich and Nobel (1957). They measured the frictional force between the body and the couch when traction was applied. The mean frictional force between the

disarticulated lower body segment of cadaver (below L3/L4) and couch was found to be 27% of the total body weight. They recommended the use of a split table to eliminate the frictional force, and this has now become a very common clinical practice.

A radiographic study of Colachis and Strohm (1969) demonstrated that with the patient in the Fowler's position, lumbar traction generally caused decreases in anterior disc heights and increases in posterior disc heights. These changes were associated with flattening of the lordosis. In a later study (Reilly et al 1979), it was shown that the changes in disc heights were greater as the angle of hip flexion increased. Furthermore, Colachis and Strohm (1969) observed that the spine returned to its original position 10 minutes after the traction force was removed. Twomey (1985) examined the displacements of cadaveric spines during sustained traction loading. He also found that most of the elongation of the spines was lost 30 minutes after traction.

Cyriax (1978) believed that one mechanical effect of traction was to produce negative pressure in the intervertebral disc which would "suck" back a disc protrusion. However, in their study of intradiscal pressure, Andersson et al (1983) showed this

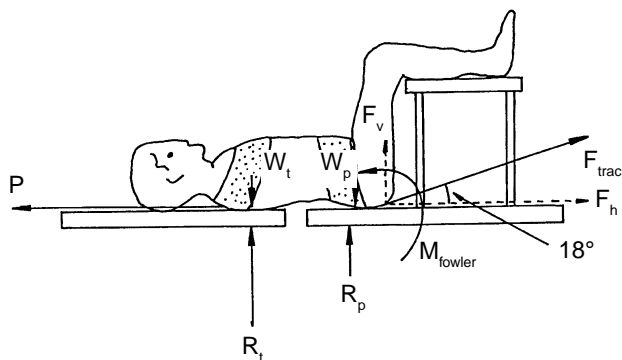


Figure 1. A free body diagram showing the loads acting on the trunk and pelvis during traction therapy on a split table with the subject in the Fowler's position. (F_{trac} = traction force, F_h = horizontal component of the traction force, F_v = vertical component of the traction force, R_p = reaction force at the pelvis, R_t = reaction force at the upper trunk, W_p = weight of the pelvis and the abdominal contents, W_t = weight of the trunk above the pelvis, P = force provided by the thoracic harness, M_{fowler} = flexion moment applied to pelvis as a result of adoption of the Fowler's position)

hypothesis to be unfounded. Although the underlying mechanisms are uncertain, there is evidence from previous radiographic and computerised tomographic studies (Gupta and Ramarao 1978, Mathews 1968, Onel et al 1989) to demonstrate that lumbar traction is capable of reducing a disc bulge.

Most previous research has dealt with the mechanical effects of traction on the anatomical structures of the lumbar spine. There is generally a lack of understanding of the nature and magnitude of loads acting on the spine during traction. Such knowledge is clinically important, as it will help to provide a basis on which to rationalise the application of the technique. The purpose of this study was thus to determine the loads acting on the lumbar spine during traction. The present study comprised a theoretical analysis of the loads acting on the spine and an experimental investigation which measured the loads imposed by the adoption of the Fowler's position.

Theoretical analysis

Figure 1 shows the loads acting on the lumbar spine during the clinical application of lumbar traction. The patient lies on a split table with the lower legs supported on a stool, adopting the Fowler's position. Clinically, a traction force of up to 350N (typically

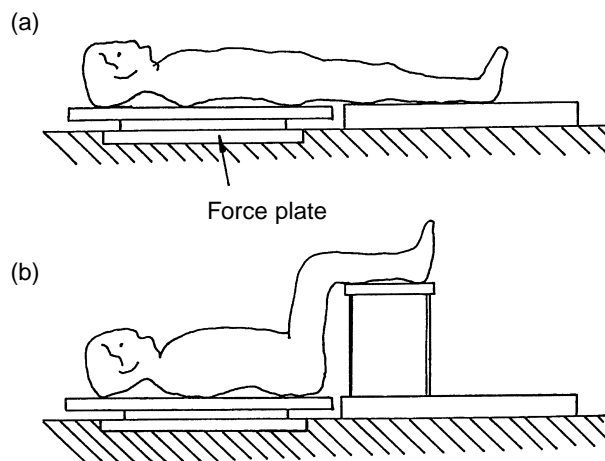


Figure 2. Experimental measurement of the hip flexion moment imposed on the spine as a result of adoption of the Fowler's position. This is given by the difference in the sagittal moment recorded by the force plate between positions (a) and (b).

about one half of body weight) may be applied and the line of pull is generally about 18 degrees to the horizontal (Colachis and Strohm 1969, Hinterbuchner 1985, Saunders 1975). As shown in Figure 1, the traction force (F_{trac}) can be resolved into horizontal (F_h) and vertical (F_v) components. If $F_{trac} = 350N$,

$$F_h = 350 \times \cos 18^\circ = 333N$$

$$F_v = 350 \times \sin 18^\circ = 108N$$

F_h provides the effective mechanical pull. This will be counteracted by an equal but opposite force (P) provided by the thoracic harness which holds the upper body in position. Since traction is normally applied through a pelvic harness which lies on the skin surface, F_h will be acting posterior to the centres of rotation of the spinal motion segments which are approximately at the geometric centres of the intervertebral discs (Gertzbein et al 1984, Rolander 1966). Therefore, F_h will produce significant flexion moment on the lumbar spine. Previous authors measured the distances between the disc centres and the overlying skin in the mid-sagittal plane on magnetic resonance imaging scans (Tracy et al 1989). The mean distances for the L2/L3 and L5/S1 segments were found to be 0.082m and 0.088m respectively, and thus the magnitude of the moment generated by F_h at these segments will be 333×0.082

= 27Nm and $333 \times 0.088 = 29\text{Nm}$.

As the weight of the calves and thighs is supported primarily by the stool, they will not impose a significant bending moment on the spine. However, Yoon and Mansour (1982) showed that the hip joint was not entirely free to rotate and that a resistive moment was found to be produced when the joint was flexed. This moment would be transmitted to the lumbar spine (M_{fowler} as shown in Figure 1) in addition to the flexion moment brought about by the traction force itself. In order to counteract the flexion moment (M_{fowler} and the moment due to the traction force), there will be increases in the reaction forces at the trunk and pelvis (R_t and R_p), which will produce anterior shear at the motion segments.

Since no information is available in the literature regarding the magnitude of the flexion moment imposed by the adoption of the Fowler's position, an experimental study was undertaken to measure this moment.

Methods

Subjects Seventeen normal subjects (nine males and eight females, aged between 20 and 24, mean height = 1.63m, mean weight = 541N) were recruited for this study. They had no history of back pain that required them to seek treatment or take time off work in the previous 12 months. They were excluded if they had undergone previous back surgery or if they had any diseases or deformities of the spine. Subjects were informed about the experimental procedure and any potential risks before they signed a written consent.

Figure 2 shows the experimental arrangement that was used to measure the moment imposed on the lumbar spine as a result of adoption of the Fowler's position. Each subject was requested to lie supine with the trunk supported on a wooden board which was placed on top of a force plate (Advanced Mechanical Technology Inc., Massachusetts USA). The pelvis was placed near the edge of the board such that the straightened legs could be supported on another independent surface which was at the same level as the board. The sagittal moment as recorded by the force plate was noted. The hips and knees were then passively flexed to 90 degrees and supported on a stool with adjustable height. The change in the sagittal moment was recorded.

Results

The change in the sagittal moment represented the moment imposed on the lumbar spine due to passive hip and knee flexion. The mean change in moment was found to be $24 \pm 6\text{Nm}$.

The mean vertical force recorded by the force plate was 411N. This represented the weight of the head, arms, trunk and pelvis of the subjects. The value was comparable with the weight of these body segments calculated according to the segmental weight properties provided by Winter (1990) ($70\% \times 541\text{N} = 379\text{N}$). It should be pointed out that any change in vertical force that was not acting on the centre of the force plate would cause a change in the moment registered by the plate. In the present experiment, the vertical force acting on the force plate did not change significantly during the adoption of the Fowler's position (less than 5%). Thus it might be concluded that the observed change in the moment truly represented the moment produced by tissue resistance as the Fowler's position was adopted.

Discussion

The theoretical analysis of this study shows that traction does not simply produce axial distraction of the spine. The mechanics of traction is more complicated than the name may imply. Traction produces a flexion moment as well as axial distraction of the lumbar spine. In addition, the spine will be subjected to anterior shear as a result of the reaction force generated at the thoracic cage (R_t).

The magnitude of the flexion moment produced by the traction force (27Nm and 29Nm at L2/L3 and L5/S1 respectively) is large, and this will produce significant deformations of the spine. The moment may account for the increases in posterior disc heights and flattening of lordosis observed during traction therapy (Colachis and Strohm 1969, Reilly et al 1979).

The experimental study shows that the adoption of the Fowler's position imposes significant flexion moment on the spine (24Nm). This experimental observation may be compared with the finding of Yoon and Mansour (1982) who reported that 60 degrees of hip flexion and 50 degrees of knee flexion would generate

a flexion moment of 15Nm at the hip. The values observed in the present study were higher, but then the hips and knees were flexed to 90 degrees.

The angle of pull of traction As mentioned earlier, most previous authors recommended an angle of pull of 18 degrees on the pelvic traction harness (Colachis and Strohm 1969, Hinterbuchner 1985, Saunders 1975). Clinically, it is important to understand how the angle of pull affects the loads acting on the lumbar spine. The vertical component of the traction force (F_v) is dependent on the angle of pull. With an angle of pull of 18 degrees, F_v (= 108N) will partially counterbalance the weight of the pelvis and the abdomen which will be about 196N (28% of the body weight of a 70kg person; Winter 1990). This will reduce the normal reaction force at pelvis (R_p) by 55% ($108/196 \times 100$). Hence, the frictional resistance between the body and the plinth will be reduced by a similar amount since the frictional resistance is directly proportional to R_p . However, it should be pointed out that although increasing the angle of pull will reduce the friction, it will also decrease F_h which provides the effective mechanical pull on the spine.

If the weight of the pelvis and the abdomen is totally counterbalanced by F_v so that there is no friction,

$$F_v = 196N$$

If the traction force is 350N, the angle of pull (θ) which will produce a F_v of 196N can be calculated as follows:

$$350 \times \sin \theta = 196N$$

$$\theta = 34^\circ$$

Hence, the angle of pull may be increased up to 34 degrees. Further increase will simply lift the pelvis off the traction couch and will not provide any further mechanical advantage. However, the consideration of frictional resistance is actually trivial in modern traction therapy, as a split table is often used to eliminate the effect of friction between the body and the couch. In this case, it is suggested that the traction force should be applied horizontally to provide the most effective mechanical pull.

Clinical significance of the Fowler's position If the aim of treatment is to produce flexion of the lumbar spine, the adoption of the Fowler's position is highly beneficial, as this will generate significant flexion moment. In the neutral position of the lumbar spine,

the posterior soft collagenous tissues are slack (Panjabi et al 1982, Percy and Tibrewal 1984). In the initial stage of flexion of the spine, the slack will be taken up when the Fowler's position is being adopted. When, subsequently, the traction force is applied, the fibres of the posterior tissues are stretched, possibly producing the various therapeutic effects which are discussed later. If traction were to be applied in the supine position, with the legs straight, a substantial proportion of the traction force would be required just to take up the tissue slack. The Fowler's position is clinically important in that it reduces the traction force required to stretch posterior tissues.

Clinical significance of the flexion moment The flexion moment produced by traction must not be overlooked, as it may produce mechanical effects on the lumbar spine that have significant clinical implications. Firstly, the flexion movement produced will lead to a reduction in anterior disc height and an increase in posterior disc height. Such changes were reported in the study of Colachis and Strohm (1969). The increase in posterior disc height implies that there will be an increase in the tension of the posterior annular fibres and the posterior longitudinal ligament.

It is hypothesised that stretching of the posterior tissues may stimulate the mechanoreceptors and reduce pain (Hinterbuchner 1985, Saunders 1975). Stretching of the posterior annulus may prevent excessive posterior movement of the disc materials and help reduce a posterior disc bulge. However, it should be pointed out that this mechanism is likely to operate only if the annular and ligamentous tissues are intact and if the tension in them is sufficiently large. In addition, this will not reduce a prolapse which has extended beyond the annular and ligamentous boundaries.

The flexion moment imposed by traction, together with the loss of lordosis, will tend to raise the intradiscal pressure (Andersson et al 1974). On the other hand, the axial distraction of the spine during traction will tend to reduce the pressure (Saunders 1979). The overall effect will thus be dependent on the relative contributions of the two mechanisms. Andersson et al (1983) found that no significant changes in intradiscal pressure were observed during traction therapy, indicating that the effects of the two mechanisms may cancel each other. The observation of Andersson et al (1983) does not support the belief that traction can "suck back" a posterior disc

Table 1. A comparison of the mechanical effects of traction and postero-anterior mobilisation.

	Traction	Postero-anterior mobilisation
Loading pattern	Flexion moment and distraction of the lumbar spine. Segments are subjected to anterior shear.	Three-point bending of the lumbar spine leading to extension moment. Segments above the mobilised vertebra are subjected to posterior shear, and those below to anterior shear.
Intervertebral foramen	Increase in foraminal volume	Decrease in foraminal volume
Posterior annulus and other posterior soft tissues	Stretches the posterior tissues	Relaxes the posterior tissues

protrusion by reducing the intradiscal pressure. It is more likely that traction reduces a disc lesion by increasing the tension in the posterior annulus and the posterior longitudinal ligament.

The flexion moment produced by traction will have an effect on the size of the intervertebral foramina. Panjabi et al (1983) demonstrated that the mean cross-sectional area of the foramina increased during flexion. Such changes were observed in both normal and degenerated spines. This supports the hypothesis that traction is capable of enlarging a pathologically narrowed foramen. A recent study by Humphreys et al (1998) showed that flexion moment had a more significant effect than axial traction in increasing the foraminal volume. Thus, if the aim of treatment is to enlarge the foramina, it will be desirable to increase the flexion moment, and the Fowler's position will be preferable to the supine position.

Traction versus mobilisation The mechanics of postero-anterior mobilisation has received much attention in recent years (Lee 1990 and 1995; Lee and Svensson 1990; Lee and Evans 1992, 1994, 1997 and 2000). This technique represents a three-point bending of the lumbar spine and produces extension of the spine. Additionally, posterior shear is induced at the motion segments above the vertebra being mobilised and anterior shear at those below. Clearly, the mechanical effects of postero-anterior mobilisation are fundamentally different from those of lumbar traction. Table 1 provides a comparison of the mechanical effects of the two techniques.

Clinically, there is generally a lack of consensus on the choice of traction and mobilisation in a given clinical situation. An understanding of the differences in their mechanics will help clinicians decide the

relative appropriateness of the two techniques. For instance, it could be argued that traction may be more helpful in regaining flexion movement of the spine, and postero-anterior mobilisation in regaining the extension movement.

As discussed, traction may help enlarge the intervertebral foramina. However, the spine is extended in the case of postero-anterior mobilisation, and this will tend to narrow the foramina. It is thus suggested that postero-anterior mobilisation is not a preferred choice of treatment when the intervertebral foramina are pathologically narrowed, and traction is the more appropriate choice if the aim of treatment is to enlarge the foramina.

The flexion movement produced by traction will stretch the posterior soft tissues, and the extension movement produced by mobilisation will tend to reduce any tension in these tissues. Consequently, patients with acute injuries of the posterior tissues may find traction more painful and less tolerable compared with postero-anterior mobilisation.

There are differences in the direction and magnitude of the intervertebral shear force produced by traction and postero-anterior mobilisation. Since the motion segments are subjected to anterior shear during traction, it should be avoided if patients have anterior translational instability, such as spondylolisthesis and spondylolysis. However, in the case of postero-anterior mobilisation, only the motion segments below the mobilised vertebra are subjected to anterior shear. If the unstable segment is above the mobilised vertebra, posterior shear will be induced in the segment. It is arguable that the posterior shear may reduce tissue strains and help relieve pain. Thus, in the case of L5/S1 spondylolisthesis or spondylolysis,

mobilisation of the sacrum is not a contraindication and may actually relieve symptoms, but mobilisation of L5 should be avoided.

Conclusion

The present study comprised a theoretical analysis and an experimental investigation in an attempt to determine the loads acting on the lumbar spine during traction. It was shown that traction produced flexion of the lumbar spine as well as axial distraction. Adoption of the Fowler's position was found to impose significant flexion moment on the spine.

The results of the theoretical and experimental studies have significant implications for clinical practice. For instance, the angle of pull affects the frictional force between the body and the traction couch. If traction is performed on a split table which will eliminate the frictional force, angling the line of traction force would be unnecessary and it would be sensible to apply the traction horizontally to provide the most effective mechanical pull. The Fowler's position imposes a flexion moment on the lumbar spine, and is essential in unfolding the posterior soft tissues so that the traction force is clinically more effective. The role of the flexion moment in stimulating mechanoreceptors, reducing a disc prolapse and increasing the foraminal volume is discussed. As there is no clinical consensus on the choice between traction and mobilisation treatments, an understanding of the loads imposed by the two treatment techniques can help to provide a rational basis for such a choice.

It is hoped that the present study will stimulate further research. This study has provided support to many mechanical hypotheses underlying traction, such as the stretching of the posterior soft tissues and the enlargement of the intervertebral foramina. These hypotheses should be further investigated by experimental studies, so that the clinical practice of traction therapy can be put on a firm scientific basis.

Authors Raymond YW Lee, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Yuk Choi Road, Hunghom, Hong Kong. E-mail: rsrlee@polyu.edu.hk (for correspondence). Prof. John H Evans, Centre for Rehabilitation Science and Engineering, Queensland University of Technology, Victoria Park Road, Kelvin Grove, Queensland 4059.

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