An Investigation into the Production of Intra-Articular Gas Bubbles and Increase in Joint Space in the Zygapophyseal joints of the Cervical Spine following Spinal Manipulation in Asymptomatic Subjects.

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I, Vincenzo Cascioli, do hereby declare that this dissertation is representative of my own work.

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DEDICATION

This research is decicated to all students involved in furthering the understanding of Chiropractic.

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ABSTRACT

Currently, no scientific evidence exits to demonstrate that radiolucent cavities, or an increase in joint space in the cervical zygapophyseal joints, occur following the manipulation of these joints. However, previous studies have demonstrated the presence of these phenomena in the metacarpophalangeal joints following the application of linear traction to these joints to the point of cavitation ("cracking").

This study was designed to determine whether such phenomena occurred in the cervical spine. Plain film and computed tomographic imaging were used for this purpose.

It was hypothesized that an increase in joint space and a decrease in joint density (radiolucent cavity) would be demonstrable following the application of the manipulation in the non-traction and particularly the traction positions of the neck.

Volunteers were screened for conformity with the inclusion criteria. Of these, 22 asymptomatic subjects were selected. The subjects were then assigned to one or two of 6 possible experimental groups.

The subjects of each group were radiographically imaged before and immediately after the manipulation.

In all cases except for Experiment 1 the subjects received :

- a *pre-manipulation* X-ray and/or CT scan,
- a *pre-manipulation plus traction* X-ray and/or CT scan,
- a *post-manipulation* X-ray and/or CT scan and
- a *post-manipulation plus traction* X-ray and/or CT scan.

A total of 83 CT scans consisting of 1660 images and 36 fluoroscopy-assisted plain-film radiographs were performed.

Pre-manipulation data (control) was compared to post-manipulation data (experimental) utilizing the Mann-Whitney U test.

Tests comparing the pre-manipulation data of experiment 2 to the post-manipulation data of experiment 2 indicated that :

- a decrease in the density readings of the joint spaces at the segmental level of manipulation and adjacent levels + 8kg traction and at the segmental level of manipulation alone + 8kg traction was present at the 5% level of significance

The results otherwise indicated that immediately following a spinal manipulation with and without cervical traction:

- the distance between the subchondral margins, the area of the zygapophyseal joint spaces, and the density values of the zygapophyseal joint spaces did not significantly change.
- No visible radiolucent cavities/vacuum phenomena were demonstrated.

In addition to the above, it was noted that the density values of the zygapophyseal joint spaces following spinal manipulation were well above the density of air (-1000) and water (0).

The above is not consistent with the current understanding of cavitation of joints, in particular to the refractory period.

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DEFINITION OF TERMS

MANIPULATION (or ADJUSTMENT as used in Fig 2)

A dynamic, high velocity thrust of controlled amplitude applied directly to the articulations of the spine. This impulse of force is administered at the end of the normal passive range of motion of the joint, causing distraction of the joint to the point of cavitation and may be accompanied by a cracking sound.

CONTACT POINT

The specific point on the subject upon which the manipulation is administered.

JOINT SPACE

For purposes of this study, it is the distance measured between the subchondral margins of the zygapophyseal joints.

CAVITATION

The mechanism of gas formation within a synovial joint, which is thought to occur upon manipulation and is known as cavitation.

RADIOLUCENT CAVITY

For purposes of this study, it is a dark, oval shaped space to be found between the articular facets of the zygapophyseal joints on the radiographs. It is characterized by a low radiographic density. It is associated with joint cavitation.

CHAPTER 1

INTRODUCTION

Cavitation or cracking sound is a common occurrence during a manipulation or an adjustment (Sandoz 1976). It is believed that the cavitation sounds are produced when the articular surfaces of the joint are sufficiently separated during an adjustment (Roston and Haines 1947, Unsworth et al. 1971, Meal and Scott 1986). Following cavitation in the metacarpophalangeal joint, the joint space is slightly increased (Unsworth et al. 1971).

A radiolucent cavity in the metacarpophalangeal joint may be demonstrated on plain film X-ray following its cavitation, which represents a collection of gas within that joint. This phenomenon may be visualized as long as sufficient traction is applied across the joint to separate its articulating surfaces. The resting, cavitated joint does not demonstrate the presence of a radiolucent cavity. (Sandoz and Neuchatel 1969). (Fig 3).

Once the joint has been cracked, it cannot be re-cracked for 15 to 30 minutes (Sandoz and Neuchatel 1969, Unsworth et al. 1971, Mierau et al. 1988, Watson et al. 1989, Brodeur 1995). This refractory period is believed to be due to the presence of a collapsed gaseous nucleus or micro-bubbles in the synovial fluid which remains unresorbed in the joint. Upon attempted re-cavitation, this gas expands to prevent a sudden drop in intra-articular pressure and thus the cracking sound does not occur. Thus re-cavitation of the joint does not occur until all the gas in the joint is completely resorbed. (Sandoz and Neuchatel 1969).

Thus, an increase in joint space and a decrease in joint density (due to the presence of a radiolucent cavity) have been demonstrated in the metacarpophalangeal joints.

The above, however, have not been demonstrated in the zygapophyseal joints of the cervical spine and it is unknown if a similar mechanism takes place in these joints.

It is hoped that this study will increase the understanding of the effects of manipulation in the cervical zygapophyseal joints in terms of joint space size and density.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this review of the literature is to set out what is known on :

- The relationship between spinal manipulation and the cavitation process,
- the current models explaining the cavitation process,
- the phenomena associated with the cavitation process,
- the modalities utilized to demonstrate these phenomena,
- related case studies, and
- a summary of the above

2.2 The relationship between spinal manipulation and the cavitation process.

In order to obtain a successful spinal manipulation, it is necessary to passively bring the joint to the end of it's range of motion. At this stage of the manipulation all joint slack is removed and a springy resistance is felt, known as the elastic barrier of resistance. (Sandoz 1976). (Fig 1).

Studies recording preload forces during the patient setup indicate that considerably less force is required for cervical spine manipulations than for thoracic or sacroiliac manipulations. These forces have been recorded to be approximately between 0 to 5N. (Herzog 1991; Herzog, Conway, Kawchuck et al. 1993).

In the next stage of the manipulation, a high velocity, low amplitude thrust is delivered which overcomes the elastic barrier of resistance. A sudden "give" is felt and a cracking sound is often heard, both of which are intimately associated with cavitation. Once cavitation has occurred, the range of motion of the joint is slightly increased into the paraphysiological zone. (Sandoz 1976). (Fig 1).

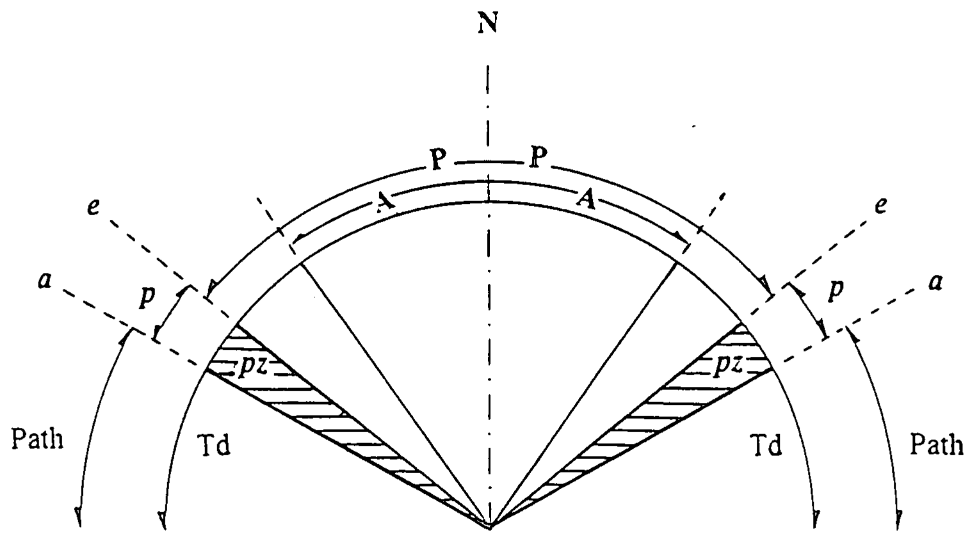
This increased range of motion may be due to :

- a decrease in the co-aptative forces within the joint due to an increased intra-articular pressure
- capsular detonisation caused by a sudden lengthening of the collagen fibers within the joint capsule. (Sandoz and Neuchatel 1969).

At the end of the paraphysiological range of motion a second barrier of resistance is felt known as the limit of anatomical integrity. If the joint is forced beyond this barrier, structural damage to the joint and its surrounding tissues is likely to occur. (Sandoz 1976). (Fig 1).

Figure 1 : Schematic representation of the ranges of motion in a normal diarthrodial joint

Adapted from Sandoz R. 1976.



N : Neutral Position

A : Active Range of Motion

P : Passive Range of Motion

p : Paraphysiological Range of Motion

Path : Pathological Range of Motion

e : Elastic Barrier of Resistance

a : Anatomical Limit

pz : Paraphysiological Zone

Td : Zone of Tissue Damage

Studies recording peak forces during spinal manipulation indicate that considerably less force is required during cervical spine manipulations than during thoracic or sacroiliac manipulations. These forces have been recorded to be approximately between 99 to 140N (Herzog, Conway, Kawchuck et al. 1993; Herzog et al. 1993) and 111 to 123N (Triano 1992) respectively.

Cervical manipulations are performed faster than those performed on the thoracic and sacroiliac joints. Mean duration times for cervical manipulations have been recorded to be approximately between 90 to 120ms (Herzog, Conway, Kawchuck et al. 1993) and 200 to 300ms (Triano 1992). Time from onset of the thrusting force until peak forces are reached have been recorded to be approximately between 30 to 65ms (Kawchuck, Herzog et al. 1992; Herzog, Conway, Kawchuck et al. 1993)

During spinal manipulations, cavitation signals typically occur near the peak thrusting force on the rising phase of force production (Herzog 1991; Kawchuck, Herzog et al. 1992). However, cavitation signals also occur after the peak thrusting force has been reached, indicating that the speed of the force application plays an important role in the cavitation process (Herzog 1991; Herzog 1994).

2.3 The Current Models Explaining the Cavitation Process.

The mechanism of gas formation within a synovial joint, which is thought to occur upon its manipulation, is known as cavitation (Brodeur 1995).

In the normal resting metacarpophalangeal joint there exists a slight negative pressure of -40 to -60mmH2O (Sandoz and Neuchatel 1969). This negative pressure, which exerts a co-aptative force to approximate the articulating surfaces is an important factor in aiding joint stability and protecting its ligaments from being over-stretched (Semlak and Ferguson 1963; Sandoz and Neuchatel 1969).

When this joint is submitted to between 8 to 16kg traction, the joint slack is removed, the articular cartilages separate approximately 0.8mm (Roston, Haines 1947; Semlak, Ferguson 1963; Sandoz and Neuchatel 1969; Unsworth et al. 1971) and this space is filled with synovial fluid from the margins of the joint capsule (Brodeur 1995). (Fig 2).

Since the joint space is basically air tight, the synovial membrane, meniscoids and articular capsule become invaginated and the pressure in the joint drops as the distracting force increases (Brodeur 1995).

If this distracting force is progressively increased to the limit of possible invagination of these soft tissues, the elastic barrier of resistance will be reached (Sandoz and Neuchatel 1969; Brodeur 1995). If the applied force is then released, the joint surfaces return to their original position (Brodeur 1995).

If this force is increased to overcome the elastic barrier of resistance, the collagen fibers of the invaginated soft tissues lengthen and recoil in a centrifugal direction. As these structures recoil away from the ligament-fluid interface, the volume of the joint increases and the internal joint pressure decreases even further. When the intra-articular pressure drops to the vapor pressure of carbon dioxide, the carbon dioxide dissolved in the synovial fluid evaporates into its gaseous form. (Brodeur 1995).

The gas bubble initially appears near the ligament-fluid interface in a shape resembling that of a doughnut, but within a fraction of a second the gas bubble coalesces in the center to form a bubble between the articulating surfaces of the joint. (Brodeur 1995).

A subsequent flow of fluid into this low pressure region collapses the gas bubble in 0.01s (Unsworth et al. 1971) and within 8.3ms (Watson and Mollan 1990) releases energy in the form of a cracking sound (Unsworth et al. 1971; Mierau, Cassidy et al. 1988). The whole process of growth and collapse occurs within 0.01ms and 0.01s (Chen and Israelachvili 1991).

Following cavitation the collapsed bubble is not immediately resorbed into the synovial fluid. Instead, the gas bubble is believed to contract into a small "gaseous nucleus" or break up into "micro-bubbles" too small to be visualized by plain film imaging. (Sandoz and Neuchatel 1969).

Once the joint has been cracked, it cannot be recracked for 15 to 30 minutes (Sandoz and Neuchatel 1969; Unsworth et al. 1971; Mierau, Cassidy et al. 1988; Brodeur 1995). This refractory period is believed to be due to the presence of this collapsed gaseous nucleus or micro-bubbles in the synovial fluid which remain unresorbed in the joint for this period of time. Upon attempted re-cavitation, this gas expands preventing a sudden drop in intra-articular pressure and thus a cracking sound is unable to be elicited. Thus re-cavitation of the joint will not occur until all the gas in the joint is completely resorbed.(Sandoz and Neuchatel 1969).

Another mechanism, known as the capsular detonisation theory, may also be responsible for this refractory period. The collagen fibers of the articular capsule, when stretched beyond a certain point, are capable of being lengthened in a sudden manner without being torn. Following this sudden reduction in tone, these fibers slowly shorten to regain their original length. Thus a second cracking sound cannot be elicited until the collagen fibers have returned to their original length. (Sandoz and Neuchatel 1969).

2.4 The Phenomena Associated with the Cavitation Process.

Three phenomena are associated with cavitation in the metacarpophalangeal joint :

- an increase in joint space
- the appearance of a radiolucent cavity/vacuum phenomenon in the joint space
- and a cracking sound. (Sandoz 1976).

2.4.1 The Increase in Joint Space.

2.4.1.1 The Metacarpophalangeal joint

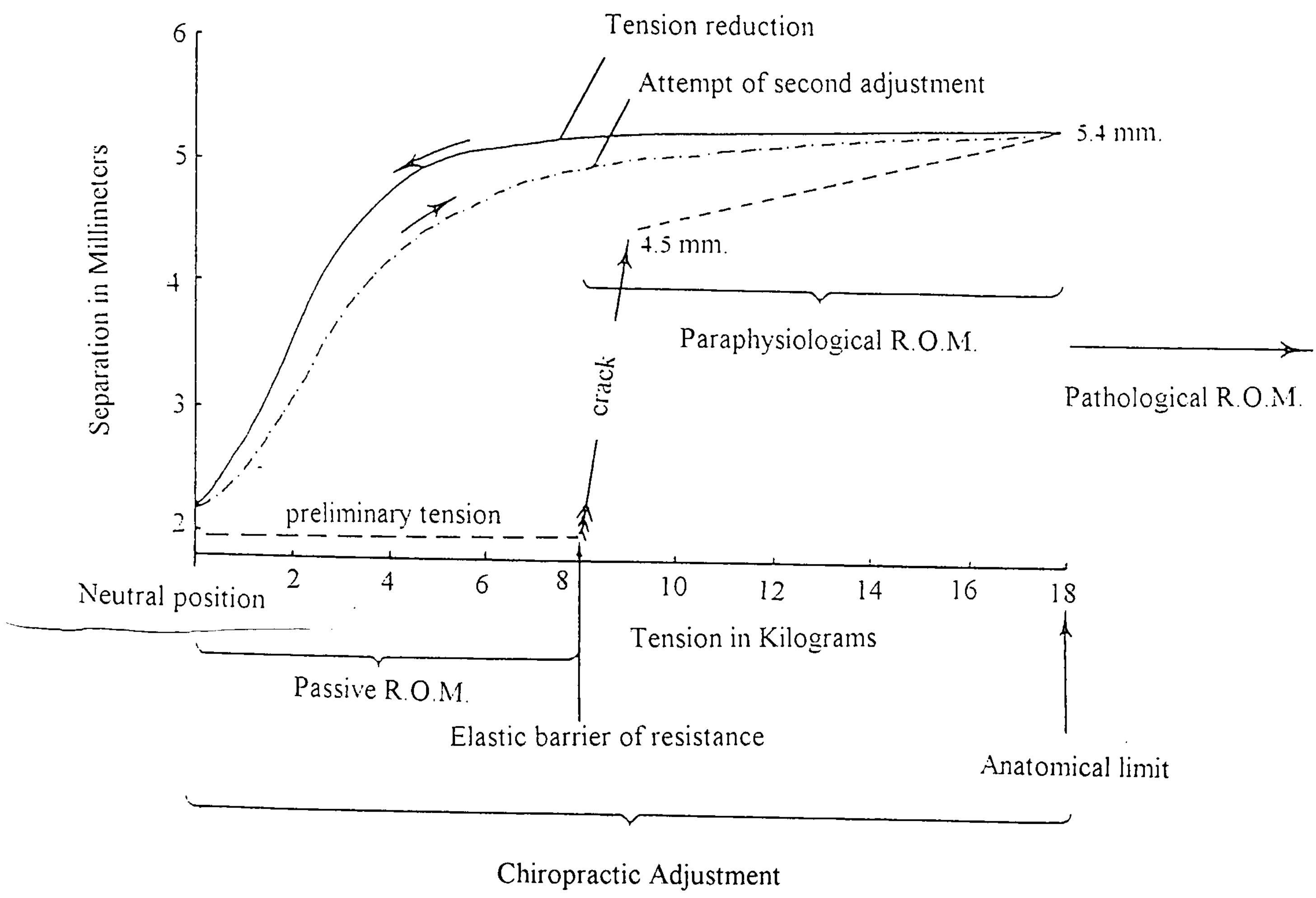
A resting pre-cavitated joint space of 0.98 to 1.8mm exists in the metacarpophalangeal joint (Unsworth <u>et al.</u> 1971; Mierau, Cassidy <u>et al.</u> 1988). This space represents the thickness of the articular cartilage and a thin film of synovial fluid. Upon the application of a maximum of 8 to 16kg traction across the joint, the joint space increases by 0.2 to 0.8mm. (Sandoz and Neuchatel 1969; Mierau, Cassidy et al. 1988). After sufficient force (usually at 8kg) has been applied to induce cavitation, a sudden separation of the joint spaces occur, increasing the joint space by a further 1.5 to 2.7mm (Roston, Haines 1947, Unsworth et al. 1971). If this traction force is increased up to 15 to 18kg an additional separation of 0.9mm occurs (Roston, Haines 1947). As this traction force is released, the joint space is still 5mm wide under 5kg of traction (Sandoz and Neuchatel 1969). See Figure 2.

If the traction force is completely released, the joint space returns to its original width (Roston, Haines 1947; Mierau, Cassidy et al. 1988). However, an increased resting post-cavitation joint space by 0.42mm five minutes after, 0.01mm ten minutes after and 0mm fifteen minutes after joint cavitation have been reported (Unsworth et al. 1971).

Upon reapplying the traction force to the cavitated joint within the refractory period, a joint separation of 4.5mm is obtained at 5kg of traction (Sandoz and Neuchatel 1969). See Figure 2.

Figure 2 : Adjustment of a carpo-metacarpal joint under axial stretch

Adapted from Sandoz R. 1976.



2.4.1.2 Cervical Spine

Upon the application of 9 to 11kg to the cervical spine, the normal lordosis is eradicated (Grieve 1982). Nobody appears to have looked for gas bubbles in the zygapophyseal joints or a change in joint space size following manipulation of the cervical spine. However, following intermittent traction at 13.5kg over 20 minutes on normal young adults, Wong et al. 1992 measured the cervical zygapophyseal joint spaces at different traction angles.

The results of this study may be tabulated as follows :

TABLE 0.1: ZYGAPOPYSEAL JOINT SPACE (IN MILLIMETERS) BEFORE AND AFTER TRACTION IN DIFFERENT TRACTION ANGLES.

	TRACTION ANGLE (MEAN +/- STANDARD DEVIATION)		
SEGMENT OF SPINE	0 DEGREES	30 DEGREES FLEXION	15 DEGREES EXTENSION
C2-C3 : BEFORE TRACTION	1.99 +/- 0.39	2.08 +/- 0.77	1.94 +/- 0.18
AFTER TRACTION	2.04 +/- 0.52	1.84 +/- 0.28	2.08 +/- 0.29
% INCREASE	2	-12	7
C3-C4 : BEFORE TRACTION	1.95 +/- 0.46	2.34+/-1.36	2.01 +/- 0.32
AFTER TRACTION	1.99 +/- 0.41	1.03+/-0.36	2.09 +/- 0.48
% INCREASE	2	-14	3
C4-C5 : BEFORE TRACTION	1.89 +/- 0.48	2.30 +/- 1.52	1.88 +/- 0.19
AFTER TRACTION	1.99 +/- 0.38	1.88 +/- 0.29	2.18 +/- 0.42
% INCREASE	5	-19	15
C5-C6 : BEFORE TRACTION	1.87 +/- 0.42	2.23 +/- 1.24	1.96 +/- 0.27
AFTER TRACTION	1.94 +/- 0.27	2.01 +/- 0.37	2.30 +/- 0.47
% INCREASE	3	-10	17
C6-C7 : BEFORE TRACTION	1.87 +/- 0.40	1.87 +/- 0.29	1.99 +/- 0.28
AFTER TRACTION	2.06 +/- 0.48	1.97 +/- 0.23	2.11 +/- 0.33
% INCREASE	10	-5	6

The above data indicates that when the neck is tractioned in forward flexion a decrease in the zygapophyseal joint space is noted, and the opposite occurs when the neck is tractioned in extension. These results will be referred to again in the discussion component of this research on page 139.

2.4.2 The Radiolucent Cavity/ Vacuum Phenomenon.

The vacuum phenomenon is a roentgenographic characteristic visualized as a radiolucent cavity in a joint space, and which represents a collection of gas within that joint. (Resnick and Niwayama 1988).

The resting cavitated joint does not demonstrate the presence of a radiolucent cavity. A radiolucent cavity may be demonstrated following the cavitation of a metacarpophalangeal joint, as long as sufficient traction is applied across the joint to separate its articulating surfaces (Sandoz and Neuchatel 1969).

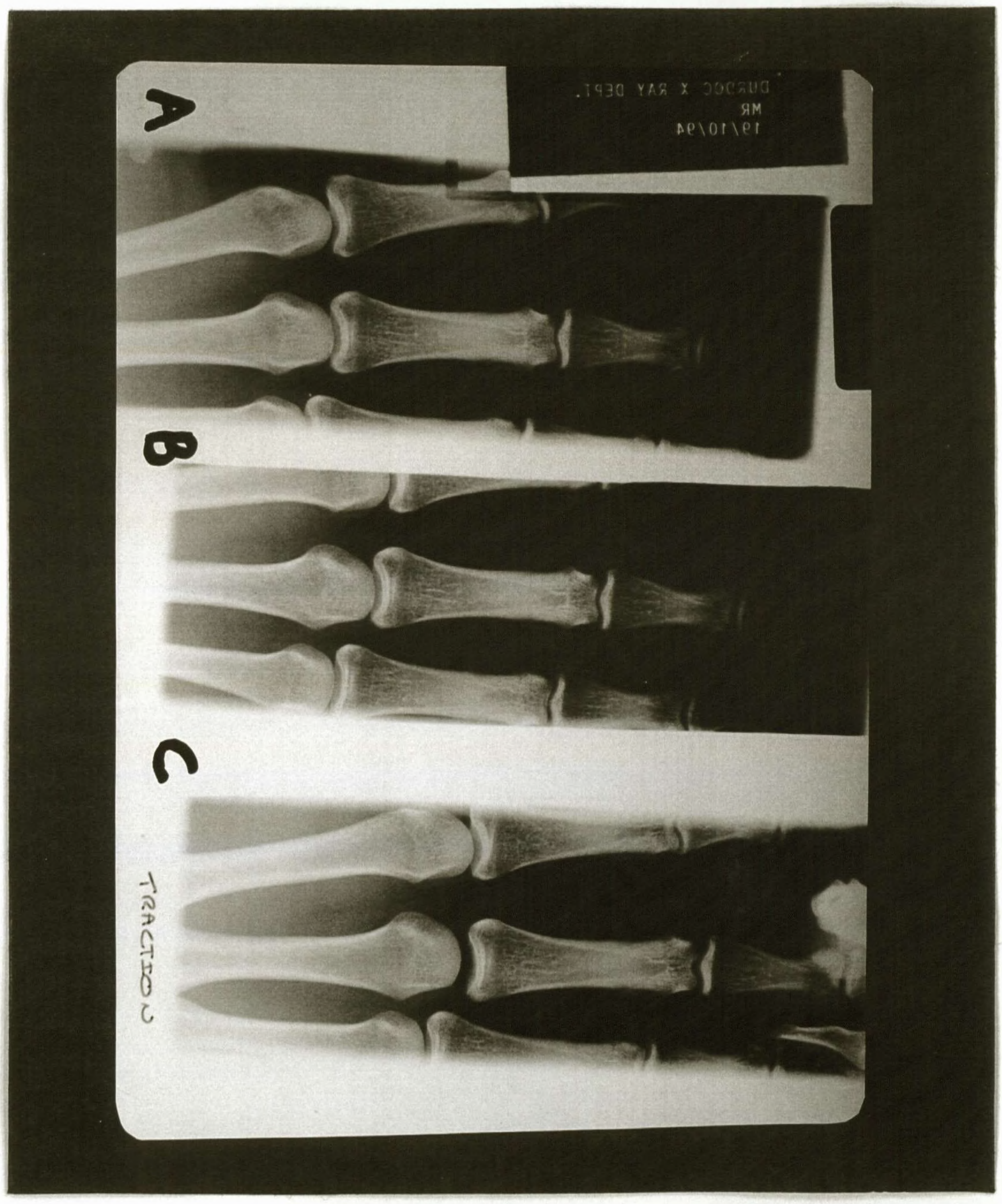
A radiolucent cavity may be demonstrated in the cavitated metacarpophalangeal joint after 10 minutes of continuous traction (Roston, Haines 1947). A radiolucent cavity may also be demonstrated in the cavitated knee joint undergoing continuous traction. However, after 2 minutes the joint space is smaller and the radiolucent cavity broken up, and after 10 minutes the joint space is as it was prior to joint cavitation. (Sandoz and Neuchatel 1969).

The above studies emphasize the importance of cavitation and traction in the demonstration of a radiolucent cavity. However, inconsistencies have been noted where 39 of 42 cavitated metacarpophalangeal joints demonstrated the presence of radiolucent cavities under 2.7kg of traction, but 3 of 42 cavitated metacarpophalangeal joints did not demonstrate the presence of radiolucent cavities under the same conditions. (Mierau, Cassidy et al. 1988). This indicates that a cavitated joint under traction will not always demonstrate a radiolucent cavity.

In addition to the above, 15 of 20 non-cavitated metacarpophalangeal joints did not demonstrate the presence of radiolucent cavities under 2.7kg of traction, but 5 of 20 non-cavitated metacarpophalangeal joints demonstrated the presence of radiolucent cavities under the same conditions. (Mierau, Cassidy et al. 1988). This indicates that the joint under traction does not have to be cavitated in order to demonstrate a radiolucent cavity.

Note in Figure 3 that : (A) represents a resting pre-cavitated metacarpophalangeal joint and it demonstrates a normal joint space and no radiolucent cavity, (B) represents a resting cavitated metacarpophalangeal joint and it demonstrates no increase in joint space (in contrast to the findings of Unsworth et al. 1971) and no radiolucent cavity, and (C) represents a cavitated metacarpophalangeal joint undergoing traction. A radiolucent cavity and increase in joint space are clearly demonstrable.

Figure 3 : A plain film radiograph. Note that a radiolucent cavity and an increase in joint space is clearly demonstrable in the metacarpophalangeal joint undergoing traction (C).



Gas analysis of the synovial fluid of 7 patients (6 rheumatoid and 1 traumatic effusion) indicates an average gas content of 15% by volume. Of this gas, over 80% is carbon dioxide. It is therefore believed that the gas created by cavitation is primarily carbon dioxide. (Unsworth et al. 1971).

In contrast to the above, gas analysis of the vacuum phenomena present in the intervertebral discs indicates that the gas is 90 to 92 percent nitrogen. The vacuum phenomenon is a frequent computed tomographic finding in patients with sciatica and is presumed to be related to the accumulation of dissolved nitrogen gases derived from the blood stream. (Resnick and Niwayama 1988).

Cineradiography utilizing a frame rate of 120 frames per second did not demonstrate the formation of a radiolucent cavity in the metacarpophalangeal joint undergoing manipulation. The formation was deduced to have occurred between two frames in less than 8.3ms (Watson and Mollan 1990).

2.4.3 The Cracking Sound.

Manipulation is often associated with an audible cracking sound which is assumed to arise from the target joint (Mierau, Cassidy et al. 1988). In the case of spinal manipulation, cavitation is assumed to occur in the zygapophyseal joints (Herzog 1994). A skilled practitioner is able to determine the success of the manipulation by hearing or feeling the joint release or cavitate (Herzog 1994).

Following diversified rotatory manipulations of the C3-C4 level, 47 of 50 subjects demonstrated cracking on the side opposite to the contact point. Of the remaining 3 subjects, one produced cracking on the side of contact and two produced bilateral cracking. (Reggars and Pollard 1995).

During the performance of L5 spinous hook and lower sacroiliac adjustments, with eight microphones taped over L3, L4, L5 and the PSIS's bilaterally, it was found that neither adjustment was associated with the cavitation of any joint/s sufficiently frequently to be of statistical significance (Beffa 1996).

The cracking sound is believed to originate from one or more stages described in the cavitation model. This sound may be caused by the "snapping" away of the joint capsule from the synovial fluid and the vibration of its collagen fibers during capsular lengthening, by the impact forces generated during the collapsing phase of the gas bubble and the vibrations of the capsule during capsular "checking" from the sudden increase in tension across the capsule when it reaches maximum displacement. (Sandoz 1976; Brodeur 1995). The energy released by this cracking sound is estimated to be 0.07mJ/mm3 (Brodeur 1995).

According to Meal and Scott (1986), the shapes of the sound waves during metacarpophalangeal and cervical zygapophyseal joint cavitation are exactly the same, that the cracking sound is a double sound wave (***PQT*** and ***TUV*** in Figure 4), and that separation of the joint surfaces and a drop in tension across the joint occurs between the two sound peaks (refer to ***S*** in figure 4).

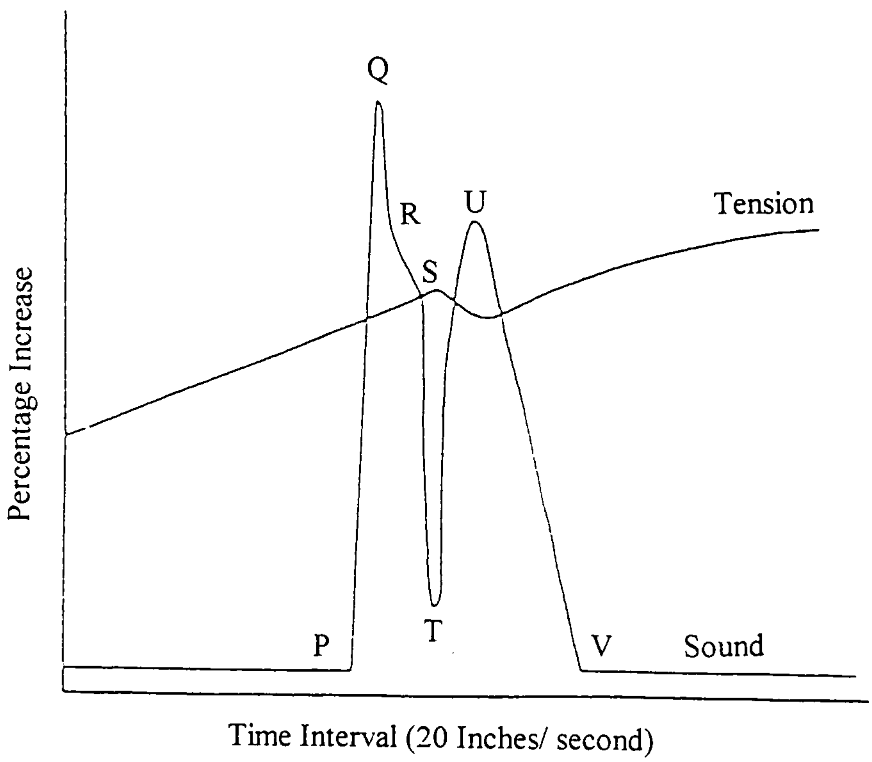
Thus, the capsular snap back and lengthening stage may account for the first sound peak and a drop in tension across the joint. The gas bubble collapse and capsular "checking" may account for the second sound peak. The average length of the cracking sound is 4ms (refer to ***PV*** in figure 4). The period of time between cracks in subjects exhibiting multiple releases is approximately 34.5ms between cracks one and two, and 8.5ms between cracks four and five. (Reggars and Pollard 1995).

In contrast to the above, cavitation signals during spinal manipulation of the T4 level are typically triphasic (3 peaks) and last for approximately 20ms (Herzog 1994).

Also, signal parameters have been found to be extremely variable (Watson et al. 1989), and cavitation signals obtained during spinal manipulation of the C3-C4 vertebral level were found to have no consistent wave form, which varied from subject to subject and even for the same subject where multiple cracks were detected (Reggars and Pollard 1995).

Figure 4 : A typical sound wave from a metacarpophalangeal joint crack with the tension trace superimposed.

Taken from Meal G.M. and Scott R.A. 1986.



2.5 The Modalities Utilized To Demonstrate The Phenomena Associated with Cavitation.

The joint space is measured from the radiograph utilizing a vernier caliper (Watson et al. 1989), a digital caliper and surgical eye loops (Mierau, Cassidy et al. 1988). Since the articular cartilage is not visible on the radiograph, the distance between the subchondral margins (Watson et al. 1989) or from cortex to cortex (Mierau, Cassidy et al. 1988) are measured.

Following manipulation, the radiograph is inspected for a radiolucent cavity which, if present, is recognized as a radiolucent crescent or D-shaped darkened area between the articular cartilages (Roston, Haines 1947, Unsworth et al. 1971, Watson et al. 1989).

It is hypothesized that when the traction is released after metacarpophalangeal joint cavitation, that the large, radiographically demonstrable radiolucent cavity contracts to a small gas nucleus or breaks up into micro-bubbles too small for plain film imaging to detect. Upon renewed traction, this gas expands to a size large enough to be visualized by plain film imaging. (Sandoz and Neuchatel 1969).

Since computed tomographic imaging is far more sensitive than plain-film imaging, it might be possible to better detect the presence of these gas bubbles in both their contracted and expanded states.

In computed tomographic imaging, the CT scanner calculates the linear attenuation coefficient of each pixel. Once the computer has determined this value, it is able to convert it to a new value known as the Hounsfield Unit. The Hounsfield Unit for air is -1000, for water it is 0, for dense bone +1000 and for materials with a higher attenuation coefficient than dense bone (such as a metal surgical clip) it is in excess of +1000. (Curry, Dowdey, Murry 1990 pages307-308).

The cracking sounds are studied using accelerometers (Watson et al. 1989; Herzog 1994) and microphones (Meal, Scott 1986, Reggars, Pollard 1995).

2.6 CASE STUDIES

General

Note that the histograms are in the form of line-graphs and number values (which are listed underneath the graphs). The histograms include pixel intensity values (in Hounsfield units), which represents the density of the tissues within the area of a trace created by the researcher on the computed tomographic image.

2.6.1 CASE STUDY 1

Introduction

The purpose of this case study was to investigate the effect of dislocation of the cervical zygapophyseal joint on it's intra-articular density. Since distraction of the zygapophyseal joint is believed to result in a lowering of the intra-articular density and this patient's facet joint was "distracted" to the point of dislocation, this case study endeavoured to determine whether an association existed between these two factors.

CT cervical spine

A 24 year old African female presented with an unifacetal jump at C4-C5 on the left. Three millimeter contiguous slices from C3 to C6 were performed. Histograms were created of the "joint space" between the posterior aspect of C4 articular pillar and the anterior aspect of C5 articular pillar, the space anterior to the inferior facet of C4 and the space posterior to the superior facet of C5.

The results were tabulated as follows:

TABLE 0.2: Histogram Variables for a Unifacetal Jump at C4-C5 on the Left

	Anterior to C4 facet	Between C4 and C5	Posterior to C5 facet
Average pixel intensity value	118	218	131
Standard deviation of pixel intensity value	63.4	200.6	110.6
Minimum pixel intensity value	32	16	-84
Maximum pixel intensity value	529	1066	746
Total area defined in millimeters squared	12	13	9

Discussion

Only one negative value (minimum pixel intensity) was noted posterior to the C5 facet, which was not low enough to represent a gas bubble/radiolucent cavity. Since a state of pathology existed, including possible rupture of the articular capsule, this negative finding was not surprising.

2.6.2 CASE STUDY 2

Introduction

The purpose of this case study was to create a histogram of an obvious vacuum phenomenon in an intervertebral disc and compare it's density value to the "classic" -1000 Hounsfield units for gas.

CT lumbar spine

A 46 year old white female presented with foot drop. Axial slices were performed through the lumbo-sacral spine after the administration of contrast via a lumbar puncture technique. The findings included degenerative disc change with a vacuum phenomenon at the L5-S1 level. A histogram was created of the vacuum phenomenon in the inter-vertebral disc of L5-S1.

The results were tabulated as follows:

TABLE 0.3: Histogram Variables for a Vacuum Phenomenon at L5-S1 I.V.D.

	Vacuum phenomenon in L5-S1 disc
Average pixel intensity value	-128
Standard deviation of pixel intensity value	35.1
Minimum pixel intensity value	-199
Maximum pixel intensity value	-30
Total area defined in millimeters squared	21

Discussion

The minimum, maximum and average pixel intensity values are all negative and are much closer to representing the "ideal" gas value of -1000. Thus, vacuum phenomena in the zygapophyseal joints (when present) one could expect to be of a similar density.

2.6.3 CASE STUDY 3

Introduction

The purpose of this case study was to create a histogram of an obvious vacuum phenomenon in the sacroiliac joints and compare it's density value to the "classic" -1000 Hounsfield units for gas. In addition to this, histograms of other tissues were made so that they could be compared with those representing the vacuum phenomena.

CT lumbar-sacral spine

A 51 year old female presented with back pain. Axial slices were performed through the lumbar-sacral spine. The findings included vacuum phenomena in both sacroiliac joints and histograms were created of the vacuum phenomena in the left and right sacroiliac joints.

The results were tabulated as follows:

TABLE 0.4: Histogram Variables for Vacuum Phenomena in both Sacroiliac Joints

	Vacuum phenomenon in left SI joint	Vacuum phenomenon in right SI joint
Average pixel intensity value	-333	-203
Standard deviation of pixel intensity value	271.7	264.5
Minimum pixel intensity value	-747	-620
Maximum pixel intensity value	566	874
Total area defined in millimeters squared	23	28

Histograms were also made of bowel gas, a normal lumbar facet joint at L4-L5 and sclerotic bone on the iliac side of the sacroiliac joint.

The results were tabulated as follows:

TABLE 0.5: Histogram Variables for Bowel Gas, a Normal Lumbar Facet Joint, and Sclerotic Bone

	Bowel gas	Lumbar facet joint	Sclerotic bone
Average pixel intensity value	-829	261	1142
Standard deviation of pixel intensity value	73.5	146.4	87.5
Minimum pixel intensity value	-952	19	932
Maximum pixel intensity value	-678	683	1312
Total area defined in millimeters squared	13	22	35

Discussion

The minimum pixel intensity values of the vacuum phenomena in the sacro-iliac joints were recorded at -747 and -620 which represents the density of gas closely. Compare these figures to that of bowel gas which had a minimum pixel intensity value of -952. Minimum pixel intensity values in this range should be expected in the post-manipulation images of Experiments 3, 4, 5 and 6 of this study to represent the gas hypothesized to be present in the zygapophyseal joints following their manipulation.

2.7 SUMMARY

This study focused on the effect of cavitation in the cervical zygapophyseal joints following spinal manipulation. It was the joint in its refractory period that was specifically being addressed.

It was not unreasonable to assume that the cervical zygapophyseal joints would have responded in a similar manner as the metacarpophalangeal joints both before and after their cavitation. Thus radiolucent cavities and an increase in joint space could also have been expected to occur in the zygapophyseal joints following spinal manipulations.

In addition, the currently hypothesized "micro-bubbles" or a "contracted gaseous nucleus" that follow joint cavitation, which are too small to be demonstrated with plain film imaging, and that are present for 15 to 30 minutes after the cavitation occurs, should be demonstrable with computed tomographic imaging. (Sandoz and Neuchatel 1969; Unsworth et. al. 1971).

However, it was also possible that the cervical zygapophyseal joints would not respond in a similar manner as the metacarpophalangeal joints both before and after their cavitation. Possible causes for a lack of similar response included the anatomical position of the neck (see 2.4.1.2), the degree of the traction force (see 2.4.1.1) and the imaging modality (see 2.4.4 and 2.5) used to visualize the zygapophyseal joints.

Thus, six similar experimental groups were created which differed in terms of the anatomical position of the neck, the degree of the traction force and the imaging modality used to visualize the zygapophyseal joints.

CHAPTER 3

MATERIALS AND METHODS

3.1 The Objective

The first objective of this study was to analyze the zygapophyseal joint spaces in terms of size and density utilizing plain film and computed tomographic imaging in asymptomatic subjects before manipulation without traction and before manipulation with traction, with the neck in varying positions.

The second objective of this study was to analyze the zygapophyseal joint spaces in terms of size and density utilizing plain film and computed tomographic imaging in asymptomatic subjects after manipulation without traction and after manipulation with traction, with the neck in varying positions.

The third objective was to compare the data obtained from before the manipulation to that obtained after the manipulation utilizing Mann-Whitney U tests in order to determine if significant alterations occurred in terms of joint space size and density.

3.2 The Data

The data for this research is of two types: primary and secondary data.

3.2.1 The primary data was collected by the experimental method.

It was indicated by the following :

3.2.1.1 Densitometer readings and visual examinations of the zygapophyseal joint spaces to determine the density of the joint spaces and for evidence of radiolucent cavities on the plain film radiographs.

3.2.1.2 Average pixel intensity values, standard deviation of pixel intensity values, minimum pixel intensity values, maximum pixel intensity values, and visual examinations of the zygapophyseal joint spaces to determine the density of the joint spaces and for evidence of radiolucent cavities on the computed tomographic images.

3.2.1.3 Vernier caliper measurements in millimeters to determine the width of the joint spaces in millimeters on the plain film radiographs.

3.2.1.4 Computer software measurements in millimeters to determine the width of the joint spaces in millimeters and the total area defined in millimeters squared of the joint spaces on the computed tomographic images.

3.2.2 The secondary data was obtained through references to operator manuals and to the current literature as well as through personal discussions with chiropractors, radiologists, radiographers and an application specialist (i.e. software and hardware support staff member from General Electric).

3.3 The Research Methodology

3.3.1 Subjects

Twenty-two asymptomatic subjects were selected for participation in this study. They were all student volunteers in the chiropractic program at Technikon Natal. A case history and cervical regional examination were performed. All participants had to comply with the delimitations of this study.

The delimitations were:

- All candidates were to have no neck pain and/or headaches during the research program.
- All candidates were to be between 20 and 30 years of age.
- All candidates understood the nature of the study and gave informed consent to proceed with the research program.

3.4 The Experimental Design

This research project was divided into six experimental groups. A generalized structure of the experiments will first be given, followed by the specific structures of each experimental group.

1. PRE-MANIPULATION

Plain film or CT imaging was performed with the subject in a traction free position.

2. PRE-MANIPULATION + TRACTION

Plain film or CT imaging was performed with the subject in a tractioned position.

A cervical manipulation between C2 and C5 segmental levels was then performed.

3. POST-MANIPULATION

Plain film or CT imaging was performed with the subject in a traction free position.

4. POST-MANIPULATION + TRACTION

Plain film or CT imaging was performed with the subject in a tractioned position.

The subjects were assigned to one or two of six possible experimental groups. In all cases each subject was handled individually and to completion (i.e. only one subject was put through steps 1 to 4 at a time).

EXPERIMENT 1

As this Experiment was to "pilot" the rest of the study utilizing plain film imaging, only two subjects were selected for this experiment. No traction was applied in this experiment.

In this case fluoroscopy-assisted plain film imaging was performed utilizing a Phillips Diagnost 92 fluoroscopy and X-ray unit, 24*30cm Curex cassettes(RPI) and a Cronex T5A processor.

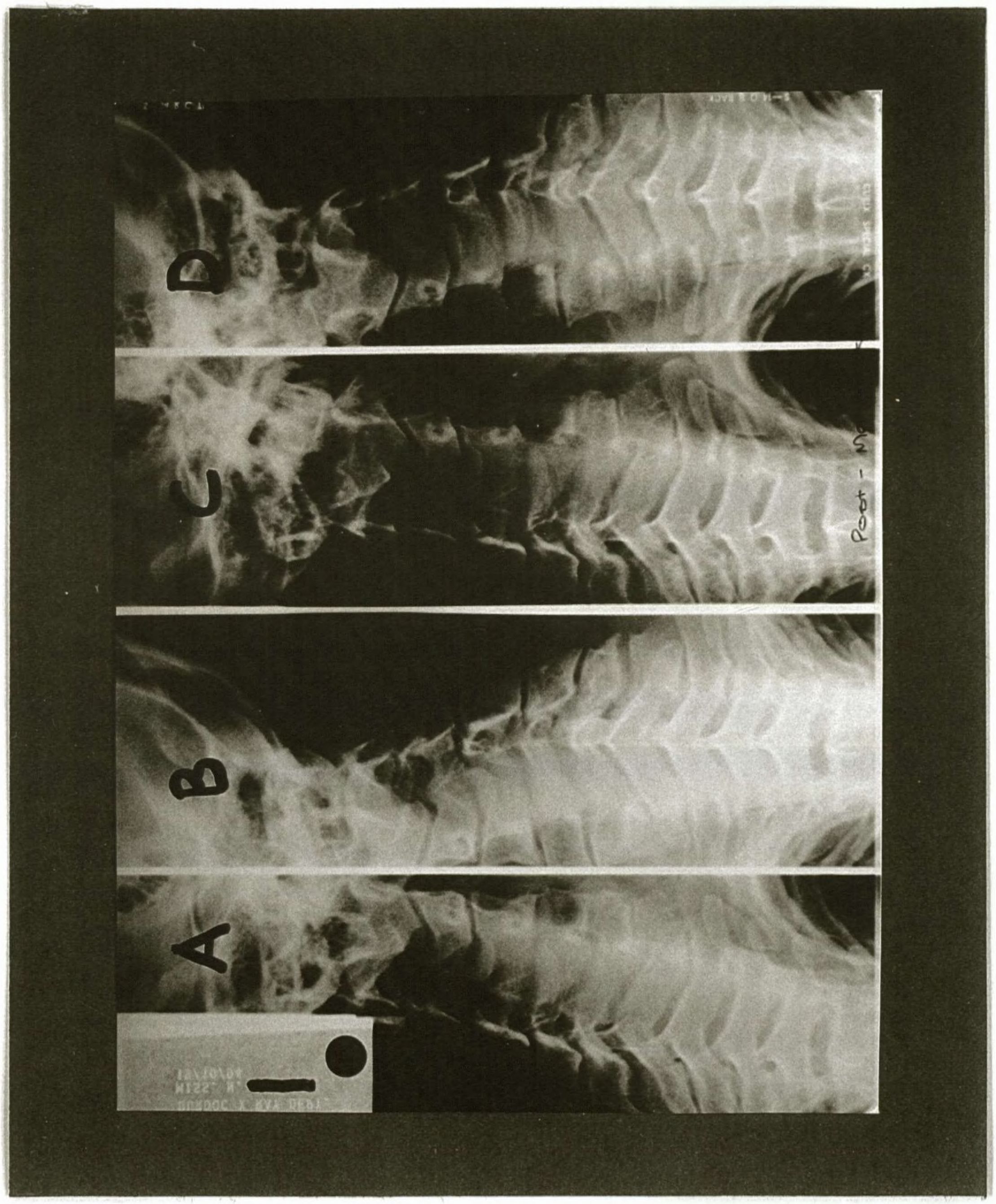
1. The subject was placed supine on the X-ray table. With the assistance of fluoroscopic imaging optimum positioning of the left pillar view was achieved and an X-ray of this view was taken. An X-ray of the right pillar view was taken in similar manner. (Fig 5, A and B).

The subject remained on the X-ray table and was set up for a manipulation.

A cervical manipulation between C2 and C5 segmental levels was performed and at least one audible release was heard. The level of the contact was specific and was recorded.

2. The subject remained supine on the X-ray table. With the assistance of fluoroscopic imaging optimum positioning of the left pillar view was achieved and an X-ray of this view was taken. An X-ray of the right pillar view was taken in similar manner. (Fig 5, C and D).

Figure 5 : An example of a plain film radiograph of the resting zygapophyseal joints *before* manipulation (A and B) and the resting zygapophyseal joints *after* manipulation (C and D). This particular subject received a lateral-break adjustment at C3 on the left yielding multiple releases.



EXPERIMENT 2

Eight subjects were selected for this experiment. A traction view both before and after the manipulation was now introduced in addition to the views without traction.

The same equipment was utilized as in Experiment 1

1. The subject was placed supine on the X-ray table. With the assistance of fluoroscopic imaging optimum positioning of the left pillar view was achieved and an X-ray of this view was taken. Approximately eight kilograms of long axis traction was applied to the subjects neck and an X-ray of this view was taken (Fig 6, A and B).

2. The subject remained supine on the X-ray table. With the assistance of fluoroscopic imaging optimum positioning of the right pillar view was achieved and an X-ray of this view was taken. Approximately eight kilograms of long axis traction was applied to the subjects neck and an X-ray of this view was taken. (Fig 6, C and D).

The subject remained on the X-ray table and was set up for a manipulation.

A cervical manipulation between C2 and C5 segmental levels was performed and at least one audible release was heard. The level of the contact was specific and was recorded.

3. With the assistance of fluoroscopic imaging optimum positioning of the left pillar view was achieved and an X-ray of this view was taken. Approximately eight kilograms of long axis traction was applied to the subjects neck and an X-ray of this view was taken (Fig 7, A and B).

4. With the assistance of fluoroscopic imaging optimum positioning of the right pillar view was achieved and an X-ray of this view was taken. Approximately eight kilograms of long axis traction was applied to the subjects neck and an X-ray of this view was taken. (Fig 7, C and D).

Figure 6 : An example of a plain film radiograph of the resting zygapophyseal joints *before* manipulation (A and C) and the zygapophyseal joints *before* manipulation + 8kg traction (B and D).This particular subject received a lateral-break adjustment at C5 bilaterally yielding multiple releases

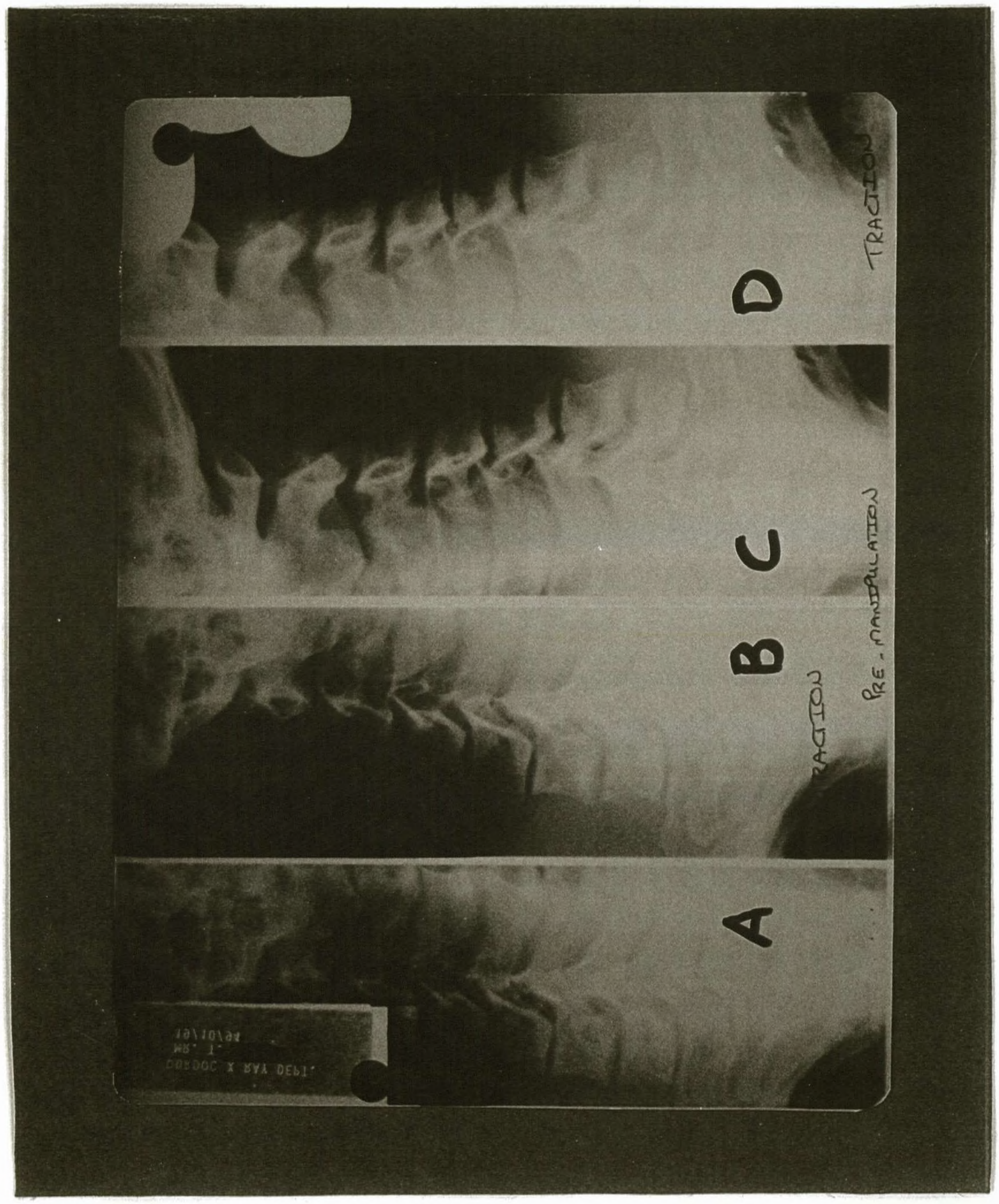
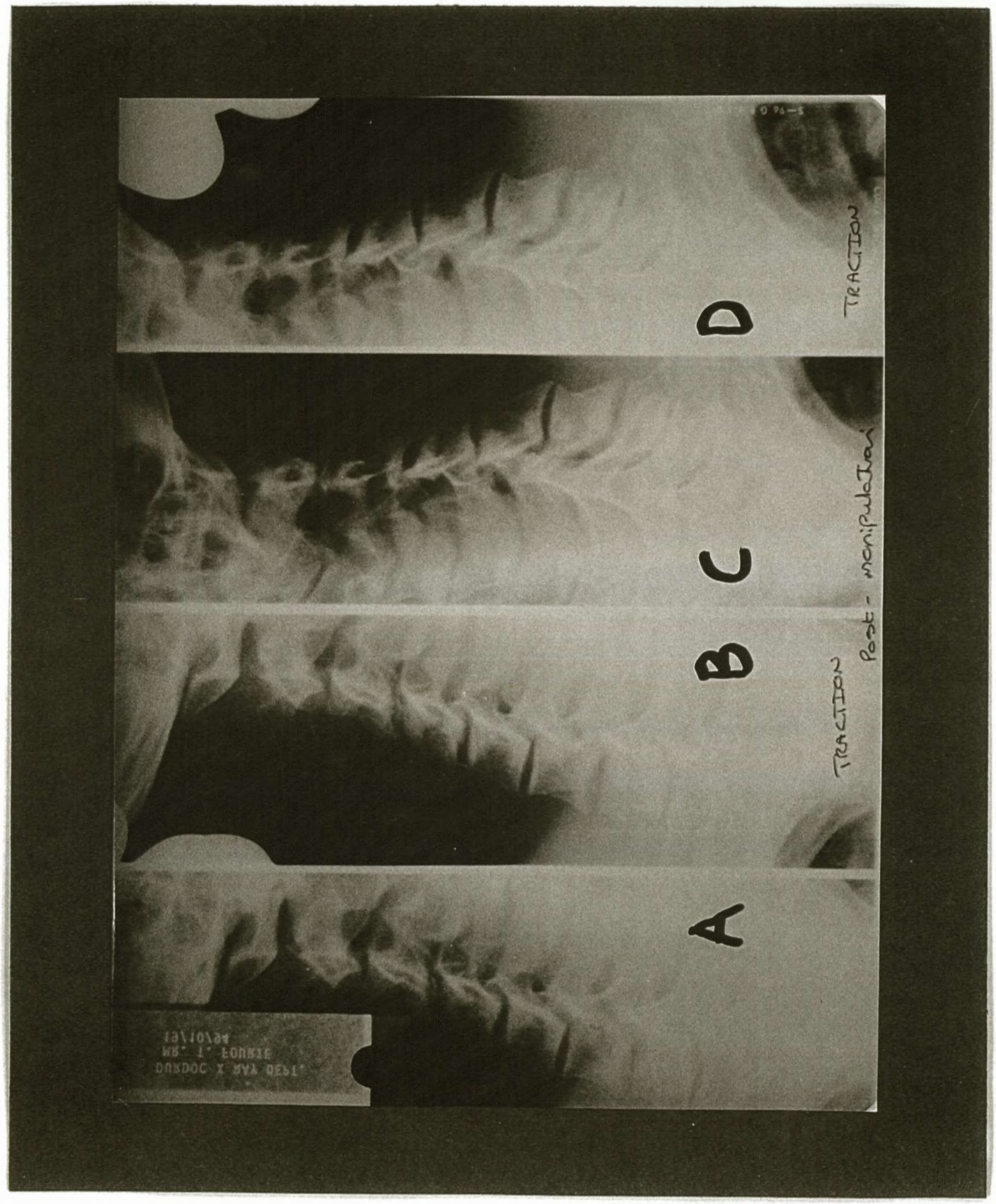


Figure 7 : An example of a plain film radiograph of the resting zygapophyseal joints *after* manipulation (A and C) and the zygapophyseal joints *after* manipulation + 8kg traction (B and D). This radiograph is of the same subject shown in figure 6.



EXPERIMENT 3

As this Experiment was to "pilot" the rest of the study utilizing computed tomographic imaging, only four subjects were selected for this experiment. Computed tomographic imaging was now introduced instead of plain film imaging since it is more sensitive and able to generate more data than is possible with plain film imaging.

In Experiments 3,4,5 and 6 computed tomographic imaging was performed utilizing a General Electric high speed CT scanner(LR458C; model number 46-29666865; year 1995), Advantage Windows software, a 3M laser camera and 35*40cm 3M film.

1. The subject was placed supine on the scanning table. A traction harness was fitted over the subject's head (Fig 8, B). The subject's head lay flat against the table with the neck parallel to the y-z plane. The subject's neck was flexed so that a goniometer (Fig 8, A) reading of the angle formed between the horizontal and a line joining the external canthus of the eye and the external auditory meatus was 120 degrees. Computed tomographic imaging of C2 to C5 was performed to include the zygapophyseal joints at the level of where the manipulation was to be performed and the adjacent segmental levels. (Fig 9).

2. The subject remained supine on the scanning table in exactly the same position. A traction cross-bar was attached to the halter. A spring balance was then attached to the cross-bar. Five kilograms of long axis traction was applied to the subject's neck and computed tomographic imaging of C2 to C5 was performed to include the zygapophyseal

joints at the level of where the manipulation was to be performed and the adjacent segmental levels whilst the traction was being applied. (Fig 10).

The subject remained on the scanning table and was set up for a manipulation.

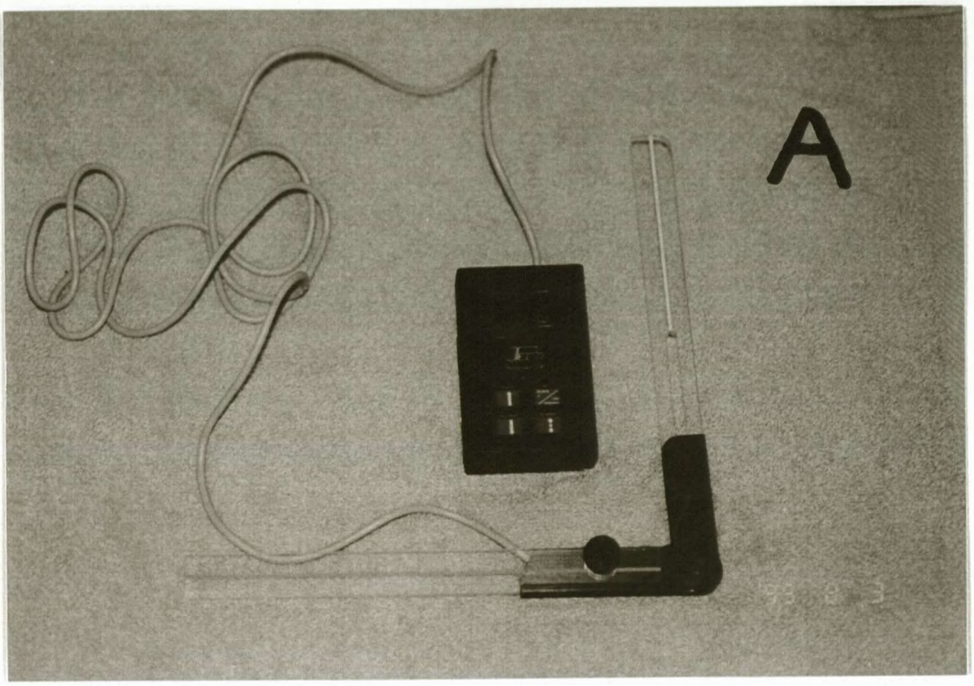
A cervical manipulation at C3 segmental level was performed and at least one audible release was heard.

3. The subject's head was replaced to the same position as described in (1). Computed tomographic imaging of C2 to C5 was performed to include the zygapophyseal joints at the level of manipulation and the adjacent segmental levels. (Fig 11).

4. The subject remained on the scanning table in exactly the same position. A traction cross-bar was attached to the halter. A spring balance was then attached to the cross-bar. Five kilograms of long axis traction was applied to the subjects neck and computed tomographic imaging of C2 to C5 was performed to include the zygapophyseal joints at the level of manipulation and the adjacent segmental levels whilst the traction was being applied. (Fig 12).

Note that the scan time ranged between thirty and sixty seconds, which was well within the refractory period of fifteen to thirty minutes.

Figure 8: Photographs of a digital goniometer (A) and the neck halter, cross bar and spring balance (B) used in this experiment. This equipment was also used in Experiments 4, 5 and 6.



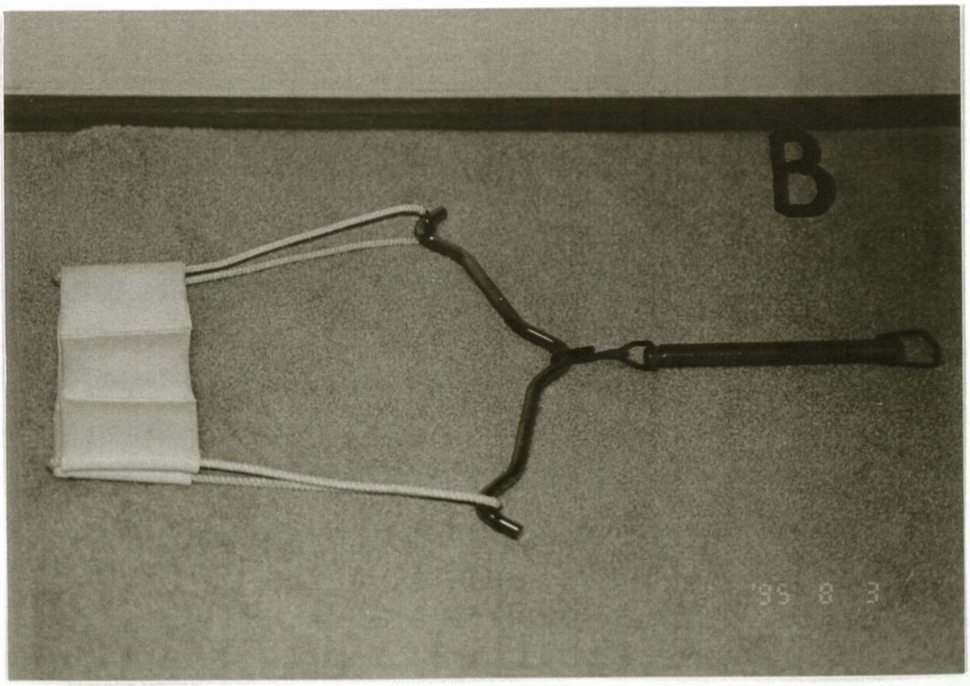


Figure 9: Experiment 3 : Pre-manipulation CT scan. Note that figures 9 to 12 represent the same subject in steps 1 to 4 of the research methodology respectively.

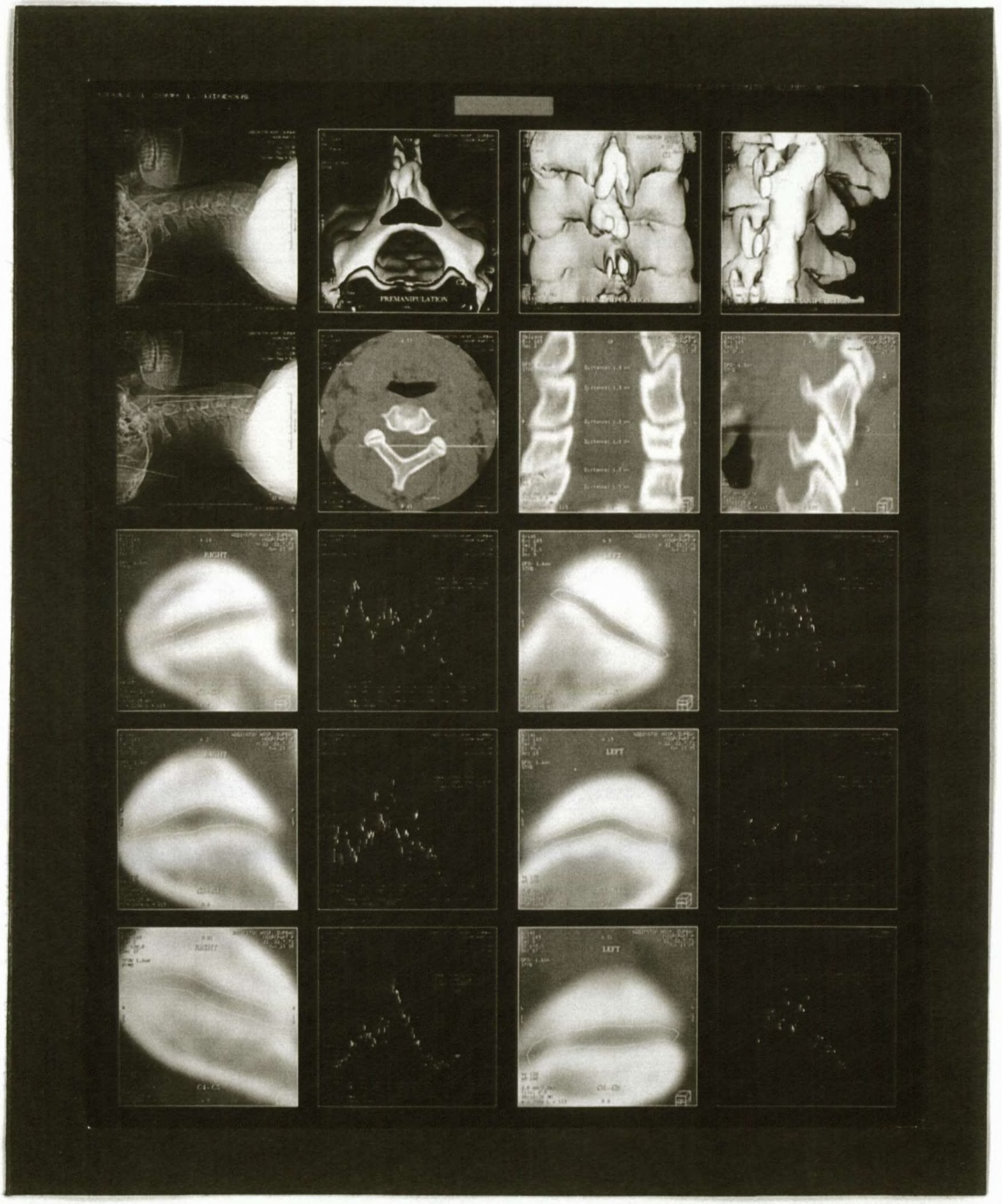


Figure 10: Experiment 3 : Pre-manipulation + 5kg traction CT scan

Figure 11 : Experiment 3 : Post-manipulation CT scan

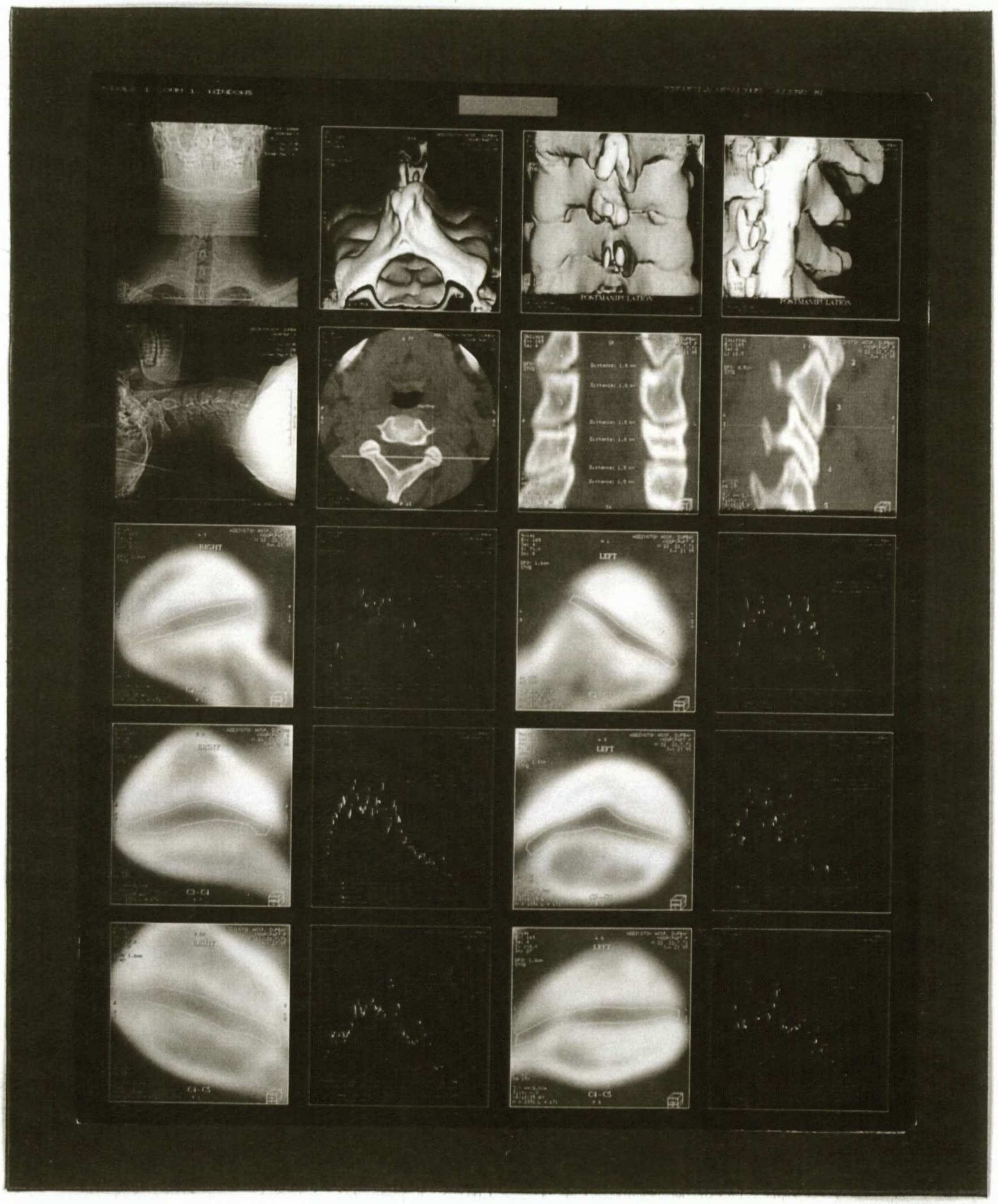
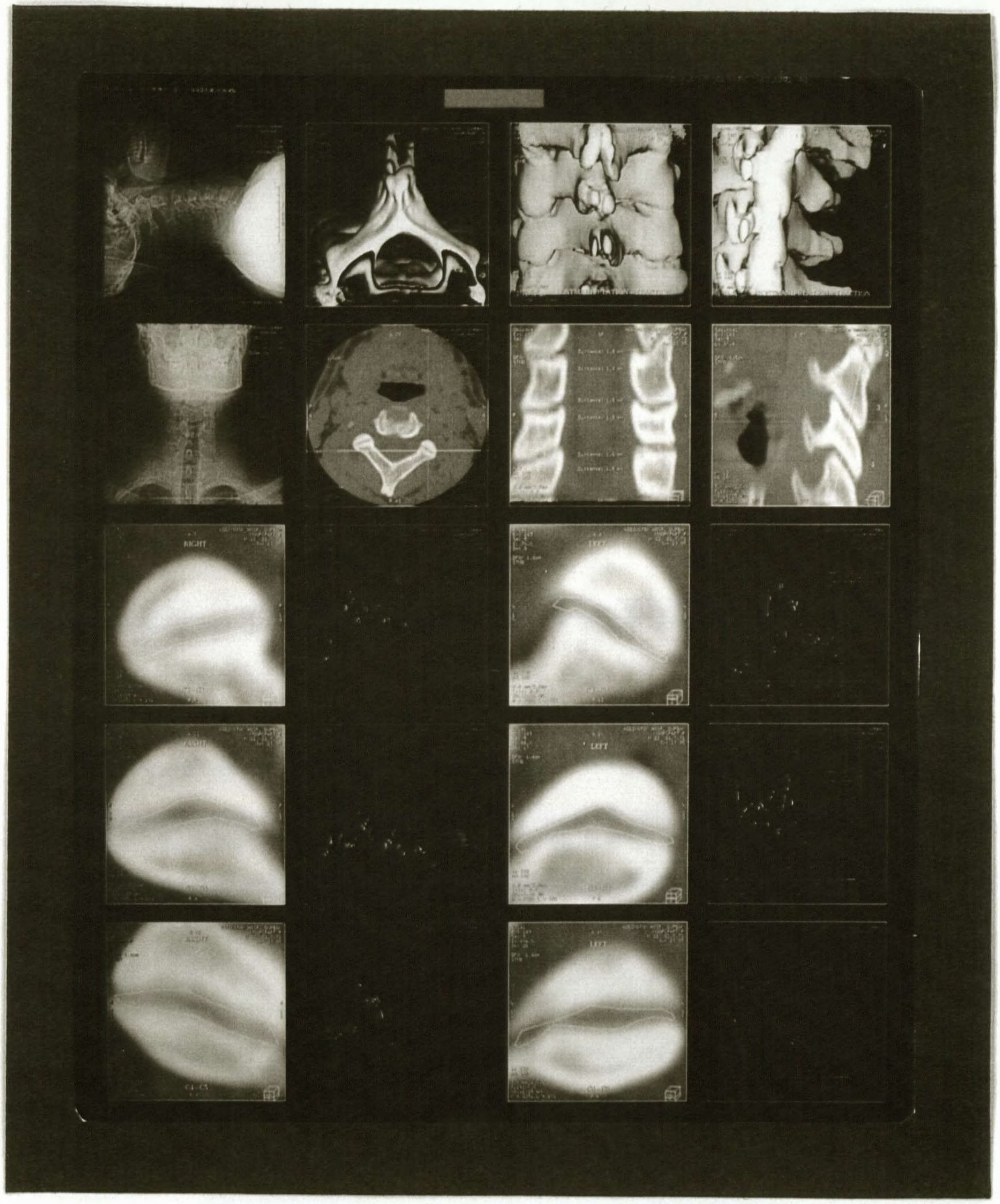


Figure 12 : Experiment 3 : Post-manipulation + 5kg traction CT scan



EXPERIMENT 4

Seven subjects were selected for this experiment. This experiment was aborted when positive results were not obvious following the imaging of these seven subjects.

1. The subject was placed supine on the scanning table. A traction halter was fitted over the subject's head. The subject's head was propped up by a 45 degree foam wedge (Fig 13, A) with the neck parallel to the y-z plane of the trunk. The subject's neck was flexed so that a goniometer reading of the angle formed between the horizontal and a line joining the external canthus of the eye and the external auditory meatus was 65 degrees. Computed tomographic imaging of C2 to C5 was performed to include the zygapophyseal joints at the level of manipulation and the adjacent segmental levels. (Fig 13, B and Fig 14).

2. The subject remained supine on the scanning table in exactly the same position. A traction cross-bar was attached to the halter. A spring balance was then attached to the cross-bar. Eight kilograms of long axis traction was applied to the subjects neck and computed tomographic imaging of C2 to C5 was performed to include the zygapophyseal joints at the level of manipulation and the adjacent segmental levels whilst the traction was being applied. (Fig 15).

The subject remained on the scanning table and was set up for a manipulation.

A cervical manipulation at C3 segmental level was performed and at least one audible release was heard.

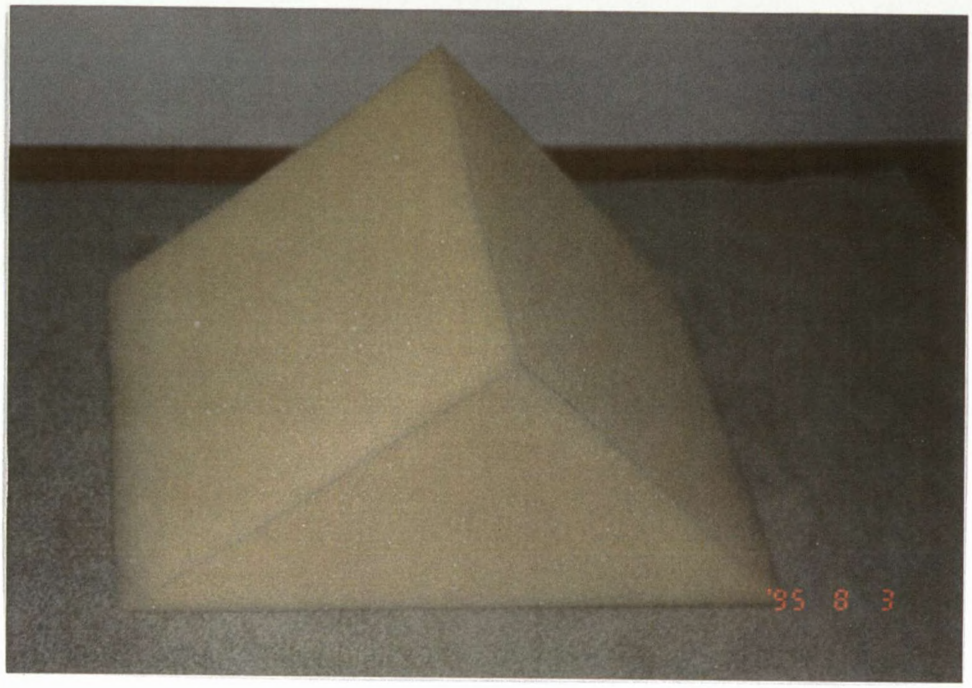
3. The subject's head was replaced to the same position as described in 1. Computed tomographic imaging of C2 to C5 was performed to include the zygapophyseal joints at the level of manipulation and the adjacent segmental levels. (Fig 16).

4. The subject remained on the scanning table in exactly the same position. A traction cross-bar was attached to the halter. A spring balance was then attached to the cross-bar. Eight kilograms of long axis traction was applied to the subjects neck and computed tomographic imaging of C2 to C5 was performed to include the zygapophyseal joints at the level of manipulation and the adjacent segmental levels whilst the traction was being applied. (Fig 17).

Note that the scan time ranged between thirty and sixty seconds which was well within the refractory period of fifteen to thirty minutes.

Figure 13: Photographs of the foam wedge used in this experiment.

A



B

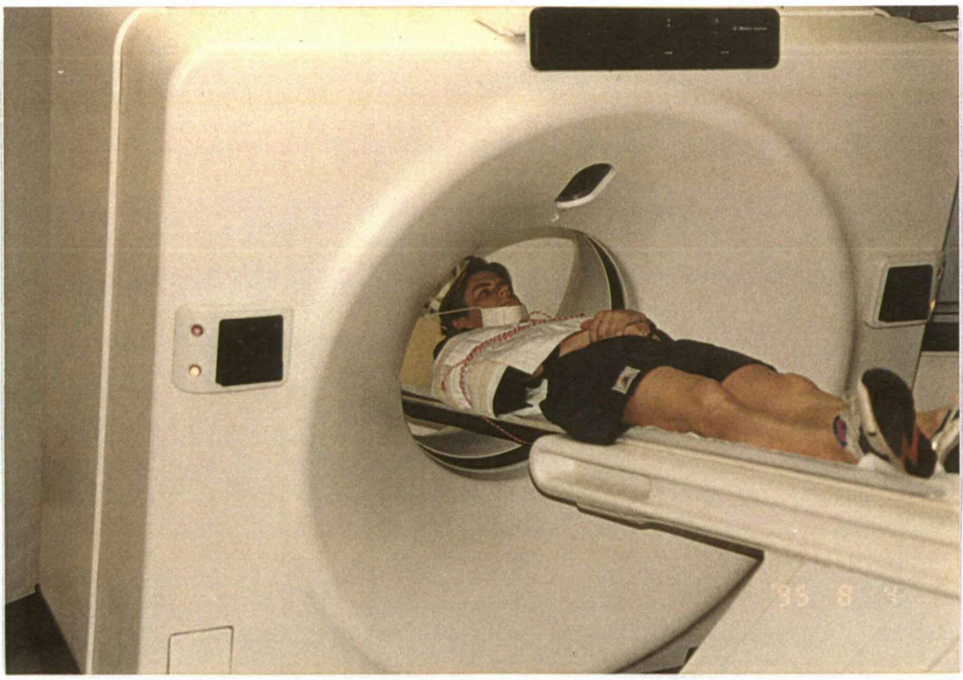


Figure 14 : Experiment 4 : Pre-manipulation CT scan. Note that figures 14 to 17 represent the same subject in steps 1 to 4 of the research methodology respectively.

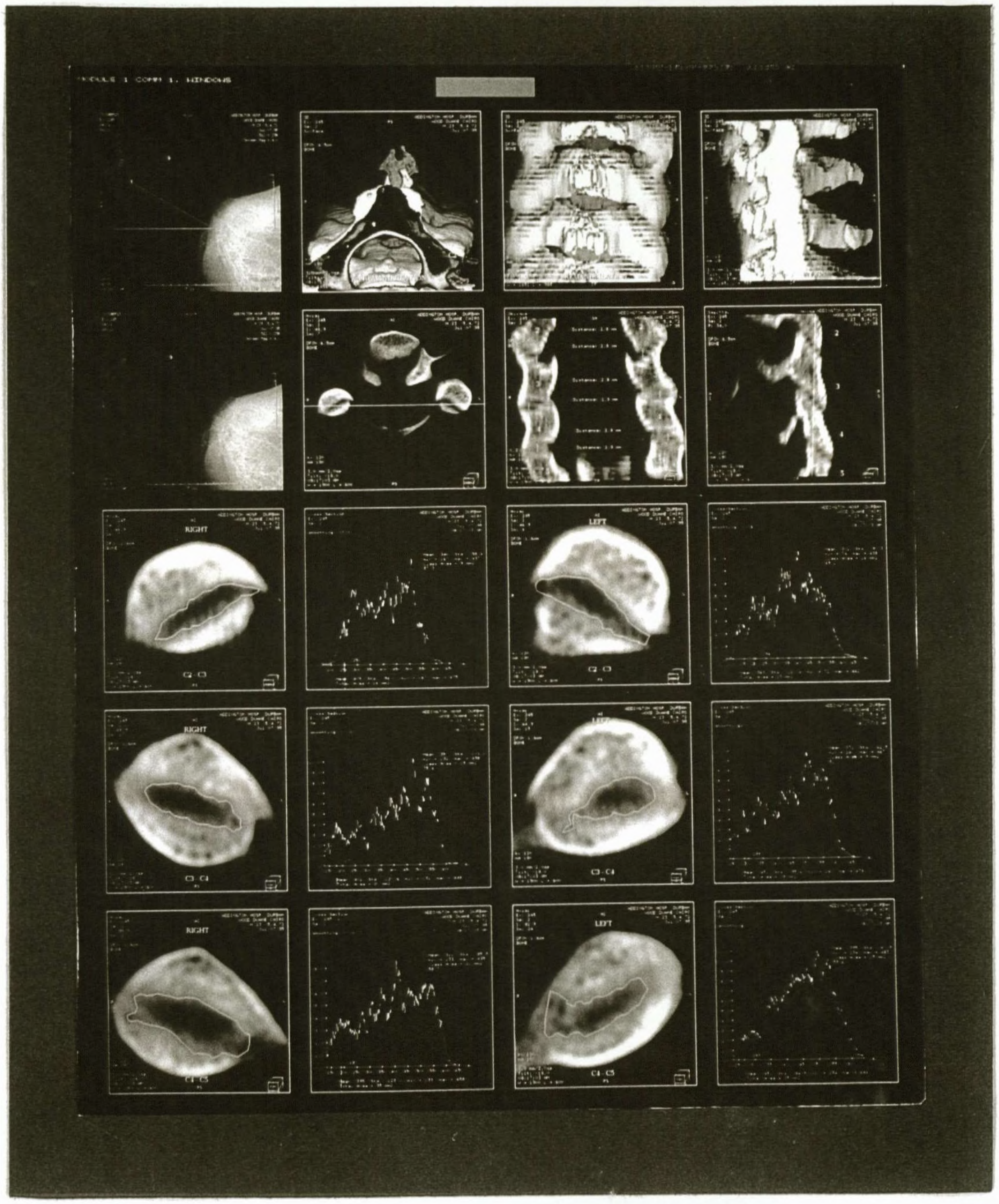


Figure 15: Experiment 4 : Pre-manipulation + 8kg traction CT scan

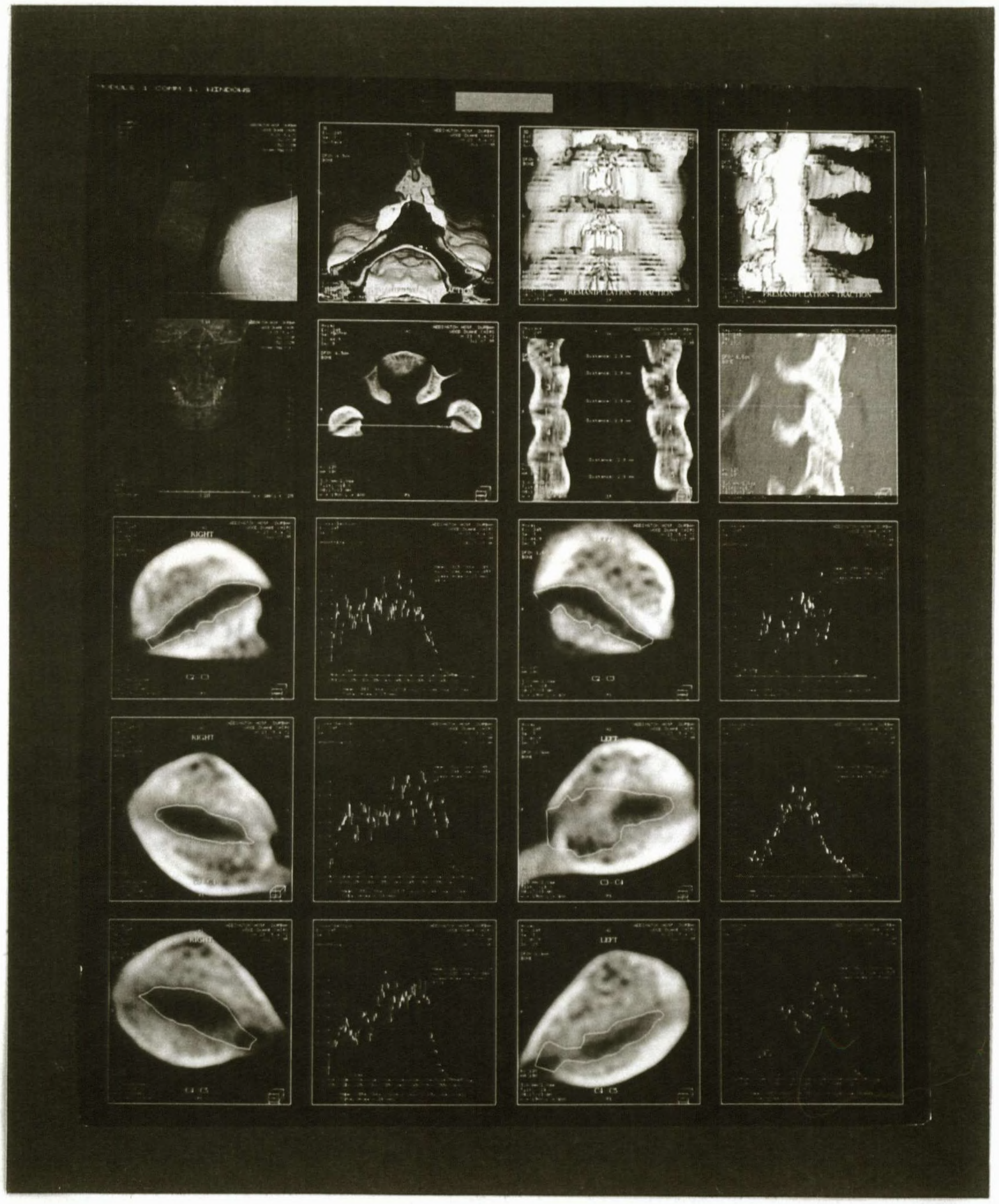


Figure 16 : Experiment 4 : Post-manipulation CT scan

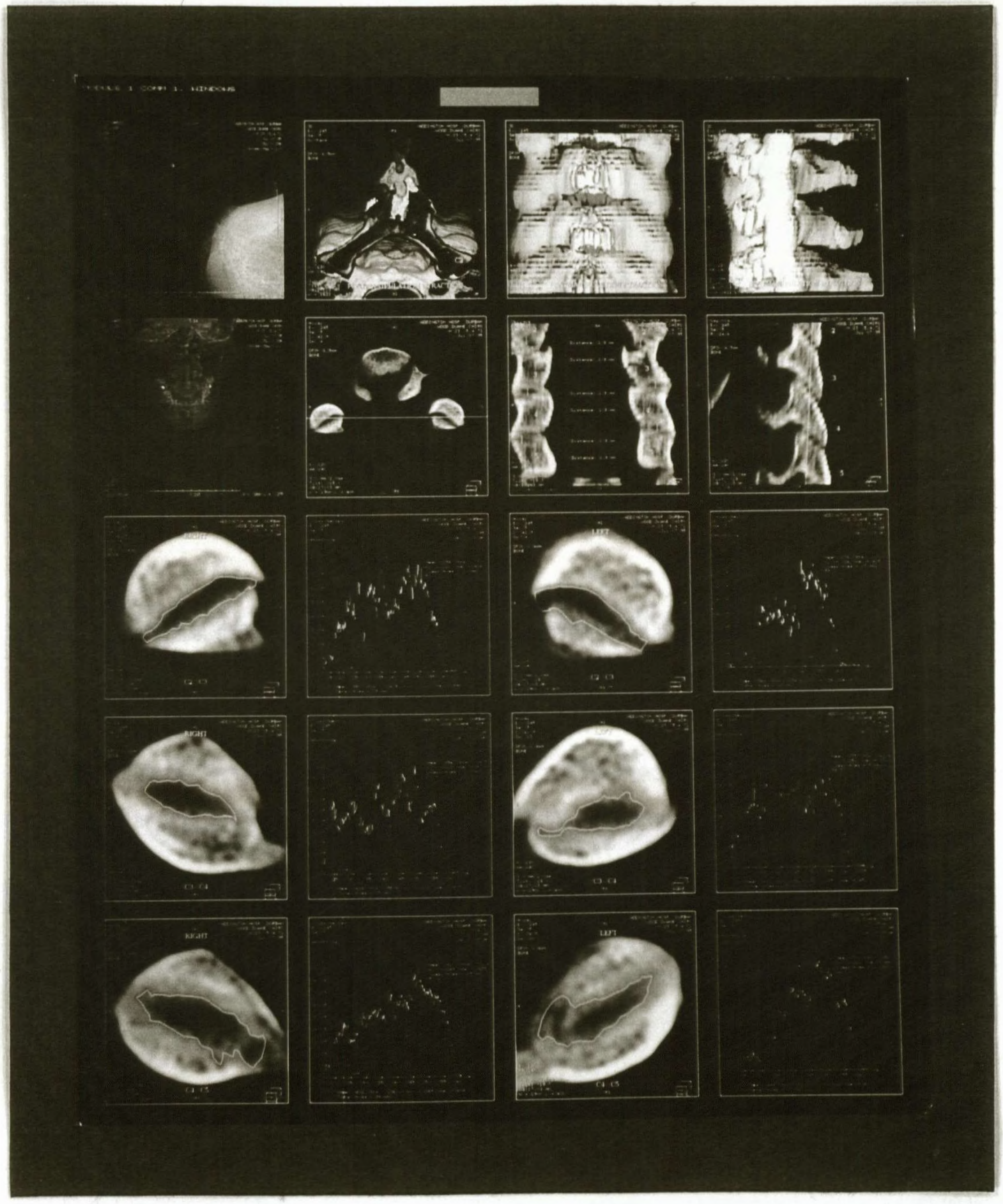
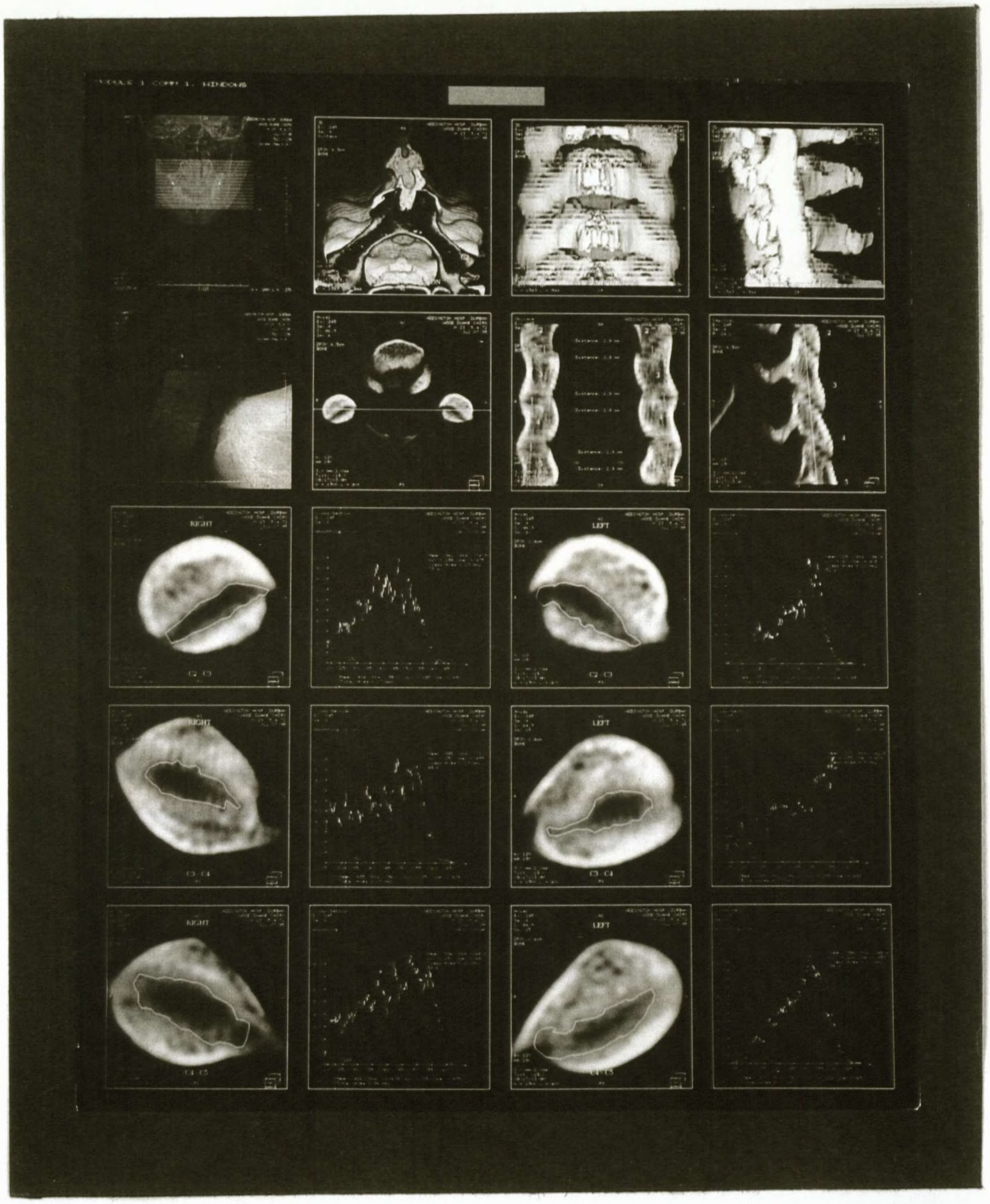


Figure 17: Experiment 4 : Post-manipulation + 8kg traction CT scan



EXPERIMENT 5

Five subjects were selected for this experiment.

1. The subject was placed supine on the scanning table. A traction halter was fitted over the subject's head. The subject's head was laterally flexed and slightly rotated (about 30 degrees) until all joint slack was removed with the fulcrum at the C3-C4 segmental level (in an attempt to maximally "open" the joint space at the segmental level of manipulation). Computed tomographic imaging of C2 to C5 was performed to include the zygapophyseal joints at the level of manipulation and the adjacent segmental levels. (Fig 18).

2. The subject remained supine on the scanning table in exactly the same position. A traction cross-bar was attached to the halter. A spring balance was then attached to the cross-bar. Eight kilograms of long axis traction was applied to the subjects neck and computed tomographic imaging of C2 to C5 was performed whilst the traction was being applied. (Fig 19).

The subject remained on the scanning table and was set up for a manipulation.

A cervical manipulation at C3 segmental level was performed and at least one audible release was heard.

3. The subject's head was replaced to the same position as described in (1). Computed tomographic imaging of C2 to C5 was performed. (Fig 20).

4. The subject remained on the scanning table in exactly the same position. A traction cross-bar was attached to the halter. A spring balance was then attached to the cross-bar. Eight kilograms of long axis traction was applied to the subjects neck and computed tomographic imaging of C2 to C5 was performed whilst the traction was being applied. (Fig 21).

Note that the scan time ranged between thirty and sixty seconds which was well within the refractory period of fifteen to thirty minutes.

Figure 18 : Experiment 5 : Pre-manipulation CT scan. Note that figures 18 to 21 represent the same subject in steps 1 to 4 of the research methodology respectively.

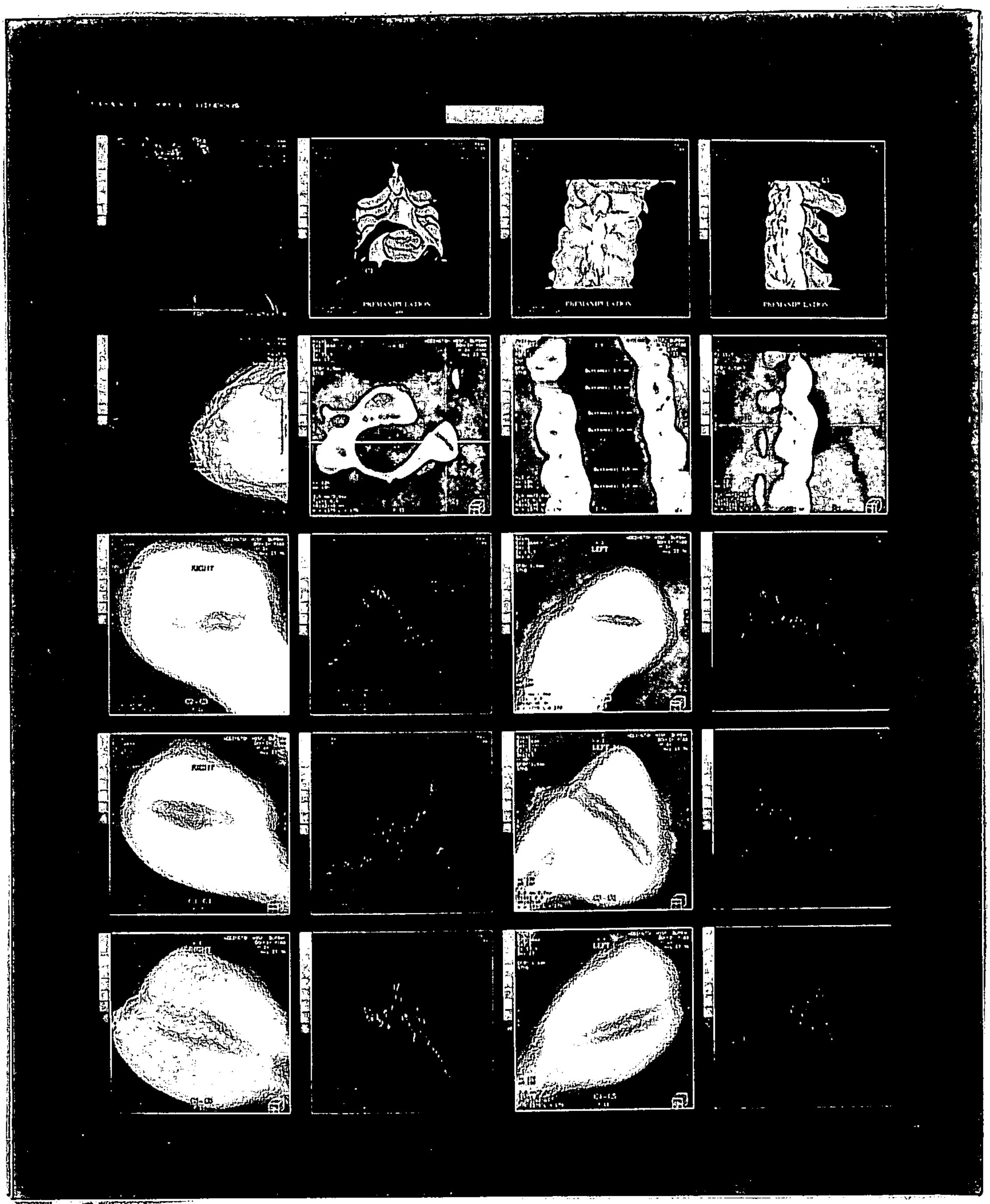


Figure 19: Experiment 5 : Pre-manipulation + 8kg traction CT scan.

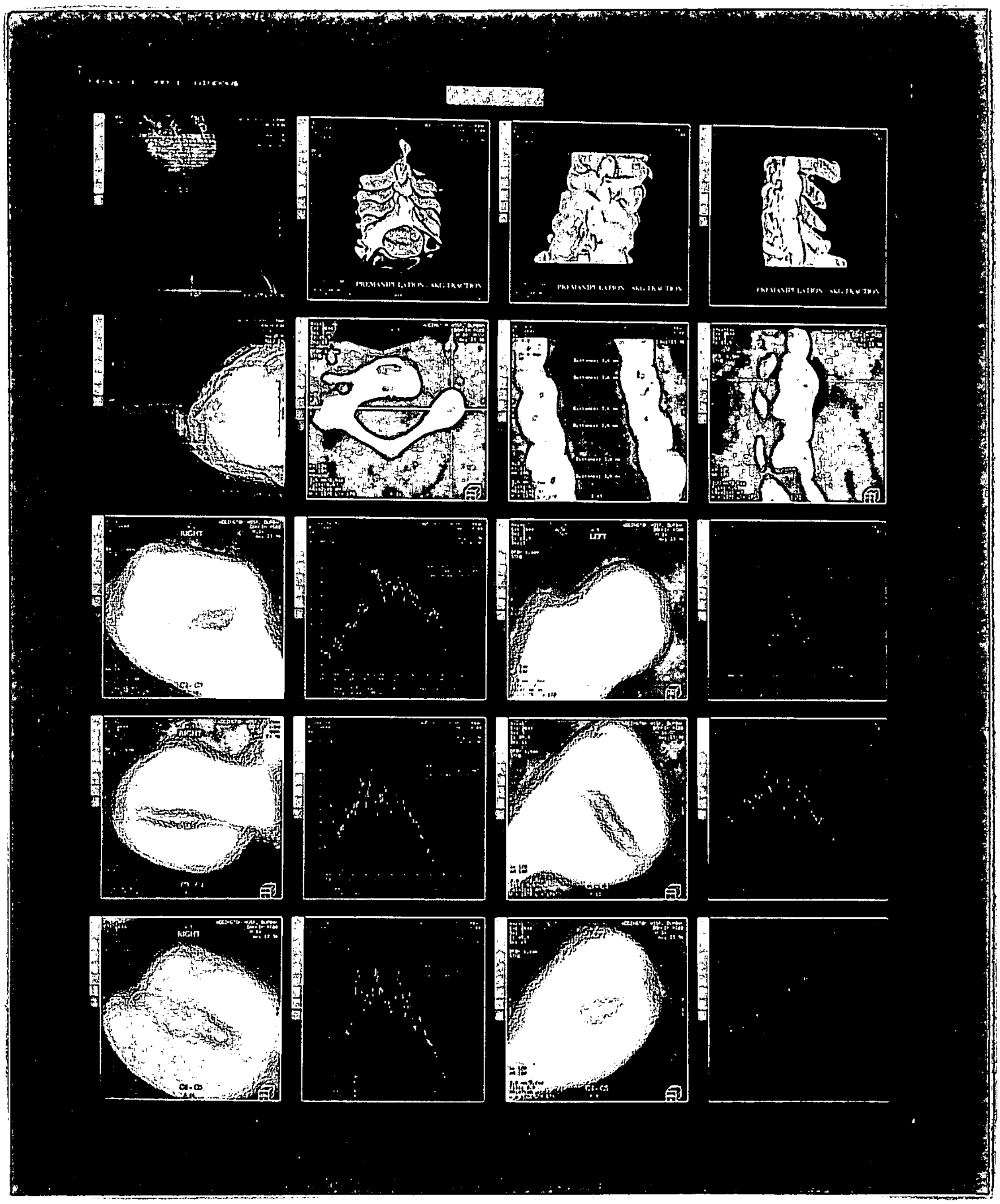


Figure 20 : Experiment 5 : Post-manipulation CT scan

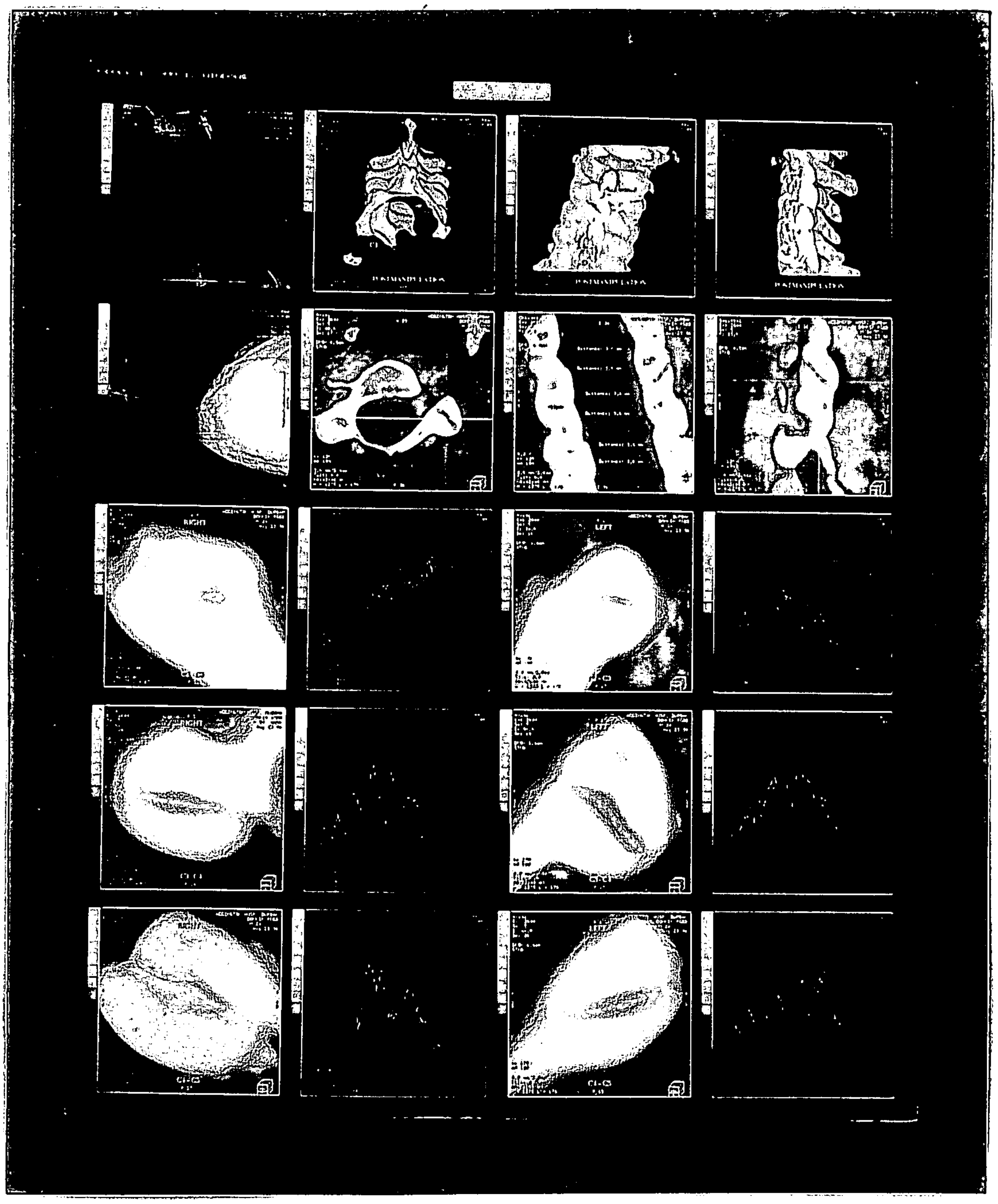
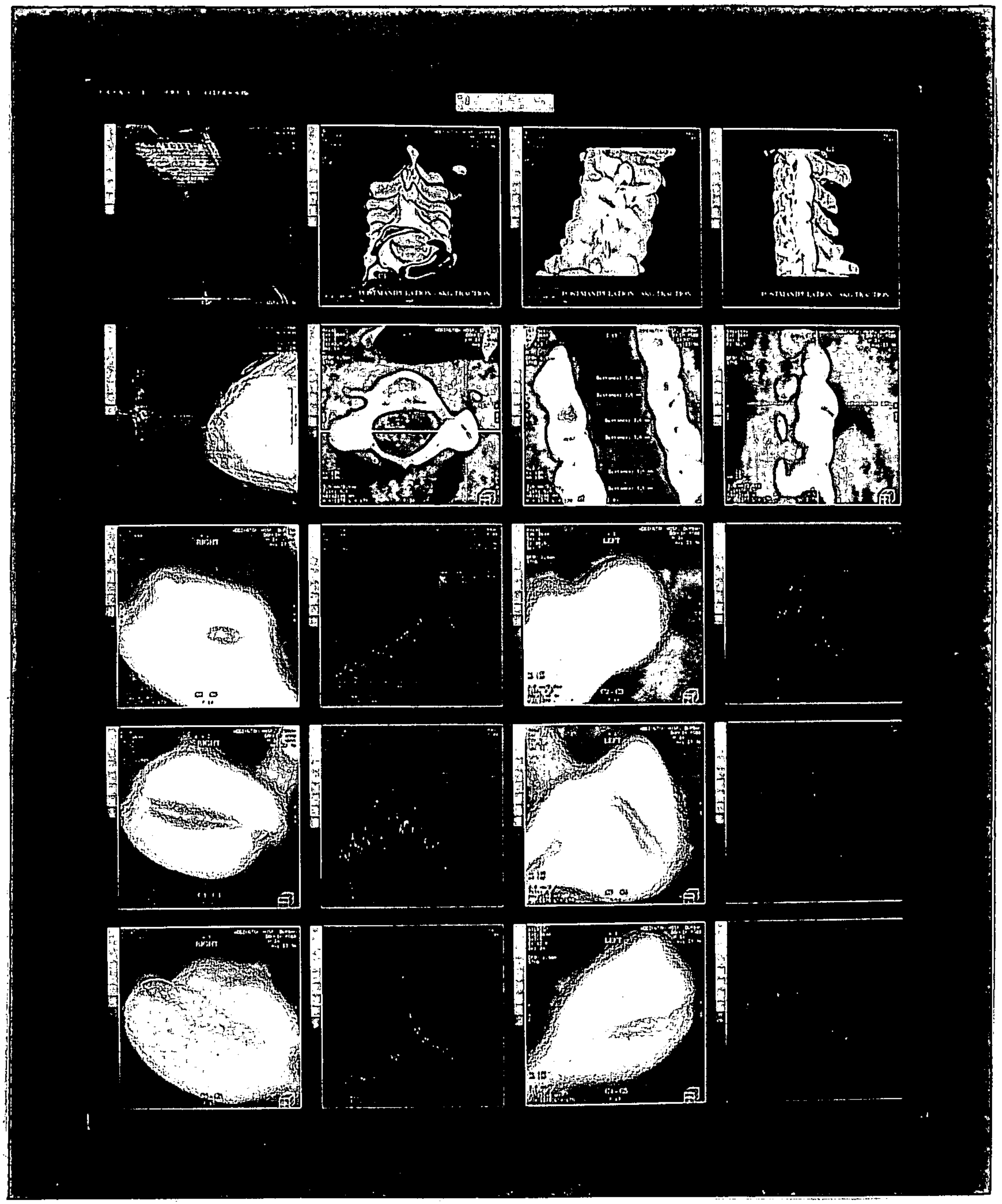


Figure 21: Experiment 5 : Post-manipulation + 8kg traction CT scan



EXPERIMENT 6

Five subjects were selected for this experiment.

In this experiment, a wooden frame was constructed with an attachment on its cephalad end for the spring balance. The frame was placed on the scanning table and the subject was placed supine on the frame and was strapped to it. Thus, a "closed circuit" of force was generated which could move along with the movements of the scanning table (Fig 22). This became necessary as the 15kg of force applied to the subject with the researcher fixed to the ground against the moving scanning table was sufficient to cause the scanner to "shut down".

1. The subject was placed supine on the wooden frame which was on the scanning table. A traction halter was fitted over the subject's head. The subject's head lay flat against the table with the neck parallel to the y-z plane. The subject's neck was flexed so that a goniometer reading of the angle formed between the horizontal and a line joining the external canthus of the eye and the external auditory meatus was 120 degrees. Computed tomographic imaging of C2 to C5 was performed. (Fig 23).

2. The subject remained supine on the scanning table in exactly the same position. A traction cross-bar was attached to the halter. A spring balance was then attached to the cross-bar. Fifteen kilograms of long axis traction was applied to the subjects neck and

computed tomographic imaging of C2 to C5 was performed whilst the traction was being applied. (Fig 24).

The subject remained on the scanning table and was set up for a manipulation.

A cervical manipulation at C3 segmental level was performed and at least one audible release was heard.

3. The subject's head was replaced to the same position as described in (1). Computed tomographic imaging of C2 to C5 was performed. (Fig 25).

4. The subject remained on the scanning table in exactly the same position. A traction cross-bar was attached to the halter. A spring balance was then attached to the cross-bar. Fifteen kilograms of long axis traction was applied to the subject's neck and computed tomographic imaging of C2 to C5 was performed whilst the traction was being applied. (Fig 26).

Note that the scan time ranged between thirty and sixty seconds which was well within the refractory period of fifteen to thirty minutes.

Figure 22: Photographs of the wooden frame used in this study.

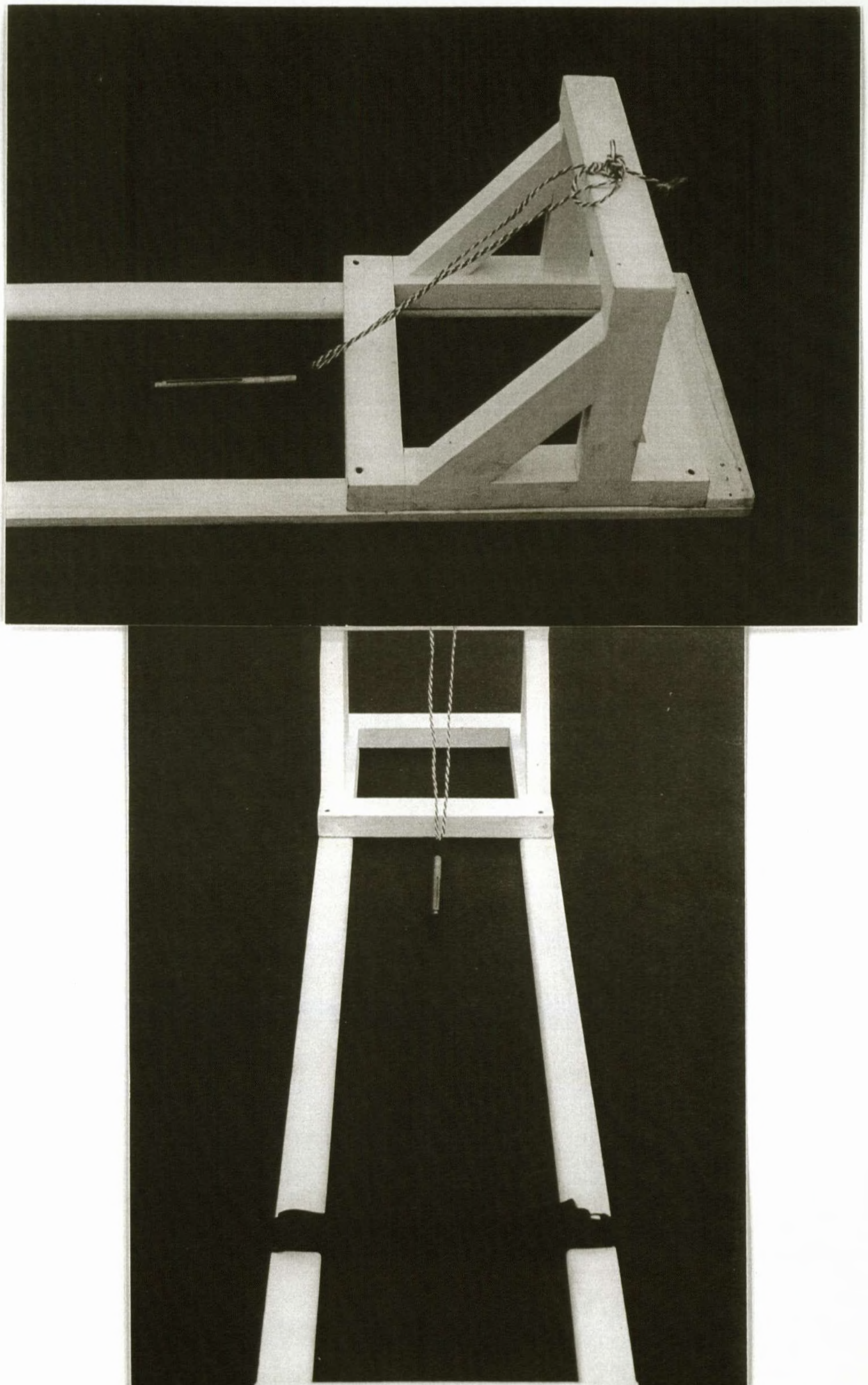


Figure 23 : Experiment 6 : Pre-manipulation CT scan. Note that figures 23 to 26 represent the same subject in steps 1 to 4 of the research methodology respectively.

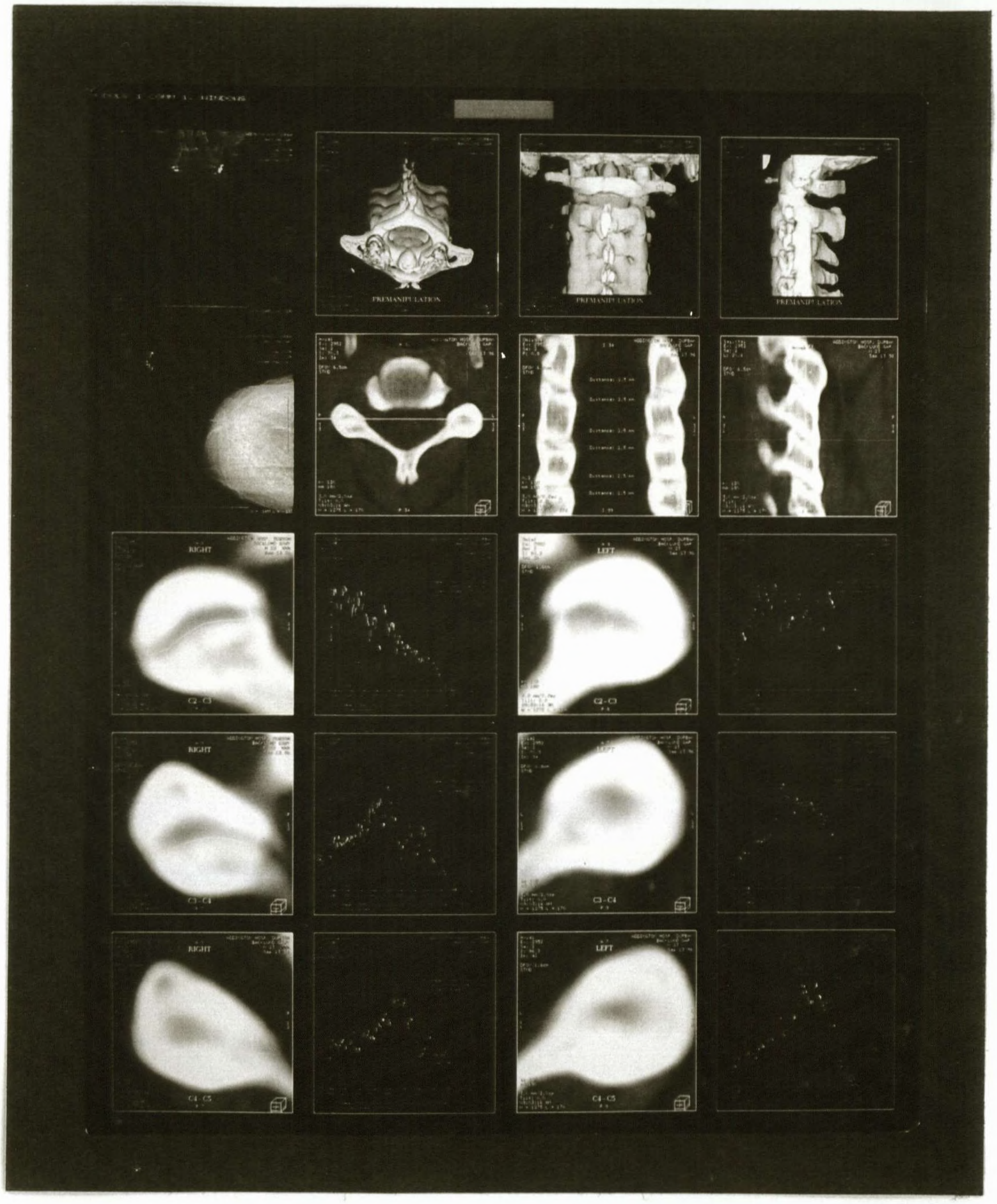


Figure 24: Experiment 6 : Pre-manipulation + 15kg traction CT scan

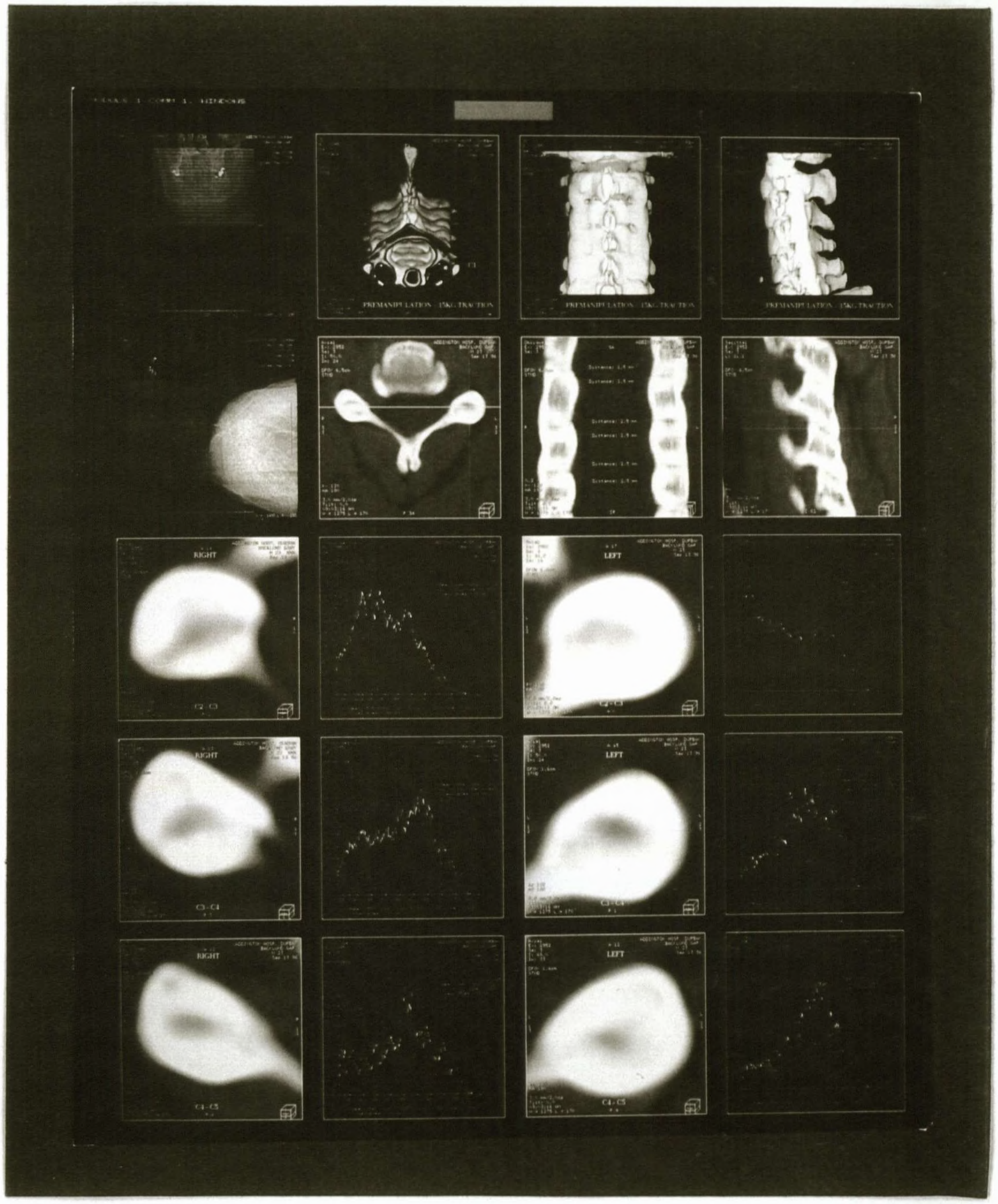


Figure 25 : Experiment 6 : Post-manipulation CT scan

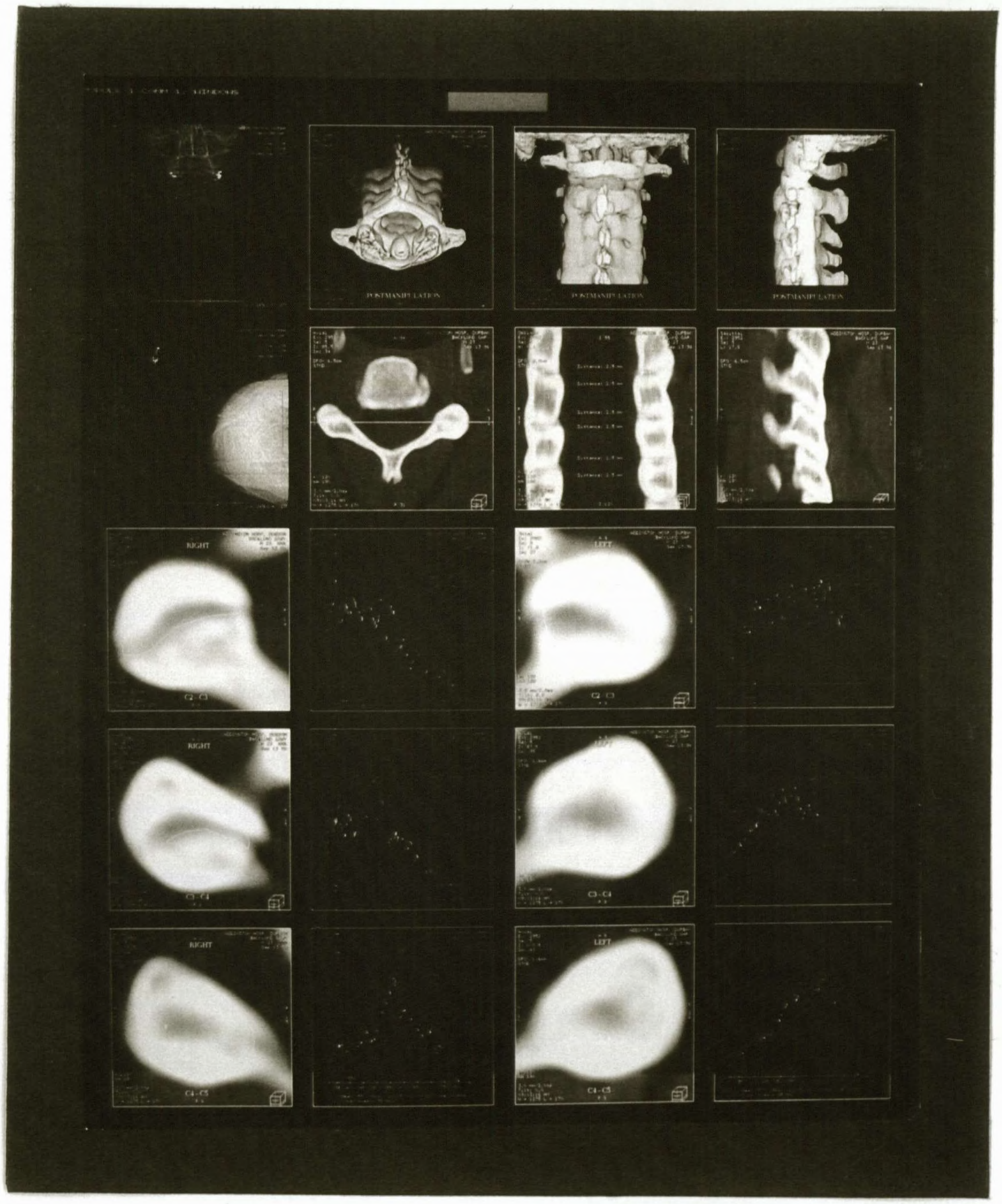
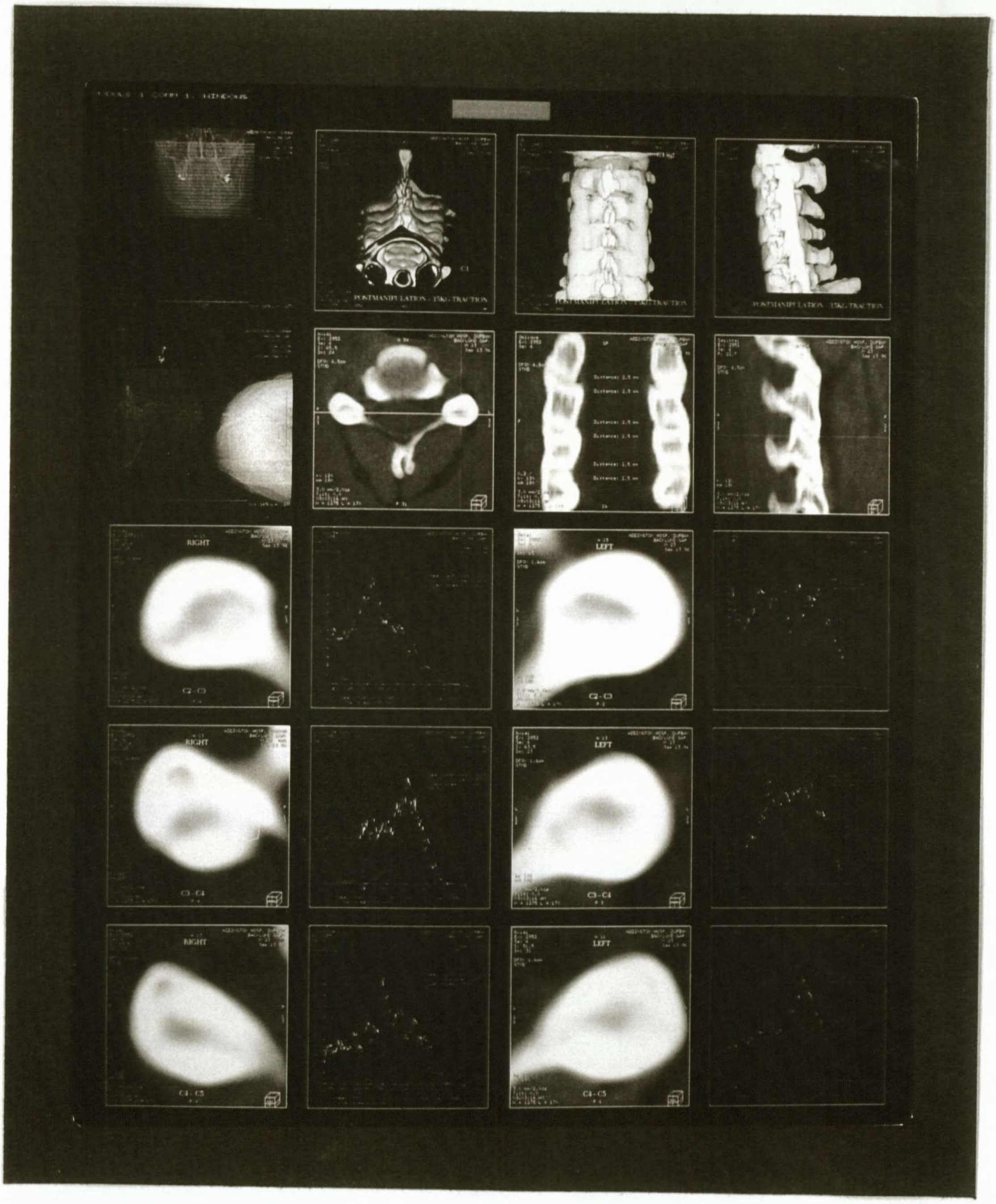


Figure 26: Experiment 6 : Post-manipulation + 15kg traction CT scan



3.5 The Means for Obtaining the Data

In the plain film studies a Vernier caliper was used to measure the width of the zygapophyseal joint spaces directly off the X-ray, whilst a densitometer was used to measure the density of these joint spaces. Furthermore, the plain films were visually examined for the presence of radiolucent cavities.

In the computed tomographic studies the images were digitally constructed on a computer as follows :

- Twenty images per radiograph were selected on the film composer.
- Lateral and A-P scout views were made.
- Three dimensional reconstruction of the cervical spine in the superior, posterior and lateral positions were made.
- Reformat views through the articular pillars in the axial, saggital and coronal planes were made. From the coronal reformat view the joint spaces between C2-C3, C3-C4 and C4-C5 bilaterally were measured utilizing computer software functions.
- Axial views of the zygapophyseal joints of C2-C3, C3-C4 and C4-C5 bilaterally were constructed.
- Histograms of the zygapophyseal joints of C2-C3, C3-C4 and C4-C5 bilaterally were constructed utilizing computer software functions. Data obtained from these histograms were the average pixel intensity value, standard deviation of pixel intensity values, minimum pixel intensity value, maximum pixel intensity value and the total area defined in millimeters squared for each joint

Once the digital construction was complete, each of the four scans (i.e. pre-manipulation, pre-manipulation + traction, post-manipulation, post-manipulation + traction) were printed onto X-ray film. The computed tomographic studies were visually examined for the presence of radiolucent cavities in the zygapophyseal joint spaces.

3.6 The Specific Treatment of the Data

EXPERIMENT 1

Each subject's plain film X-ray provided two sets of data (i.e. pre-manipulation and post-manipulation). Visual examinations of the joint spaces before and after the manipulation were performed for the presence of radiolucent cavities and these were noted in Tables 1.1 and 1.3.

Each set of data included the left and right zygapophyseal joint space density readings and joint space widths of each joint from C2 to C7. Each set of data was averaged according to the criteria stipulated in Tables 1.2 and 1.4. The averages of the above for a single subject was again averaged to the corresponding data of the other subject in this experiment.

In Experiments 1 and 2, the readings taken from all joints refers to an average of ten (i.e. C2-C7 bilaterally) joint spaces. The readings from the joints at the segmental level of manipulation and adjacent levels refers to an average of six joint spaces(i.e. the two joints at the level of manipulation - which were recorded, and the two joints above and below this level). The readings from the joints at the segmental level of manipulation refers to an average of two joint spaces(i.e. the two joints at the level of manipulation - which were recorded). This manner of grouping the data was performed so that one may more accurately determine how the manipulation influences the whole cervical spine, the joints at the segmental level of manipulation and adjacent levels, and just the joints at the segmental level of manipulation in terms of the variables used in this research.

In Table 1.1, visual examination of the plain film X-ray was performed to determine the total number of radiolucent cavities that were present before the manipulation was performed. Since the maximum number of radiolucent cavities in all the joint spaces that may be present is 10, the total is 10. The number of radiolucent cavities not demonstrated are counted and that figure is assigned to a code called a11. The "a" refers to Experiment 1, the first "1" refers to a particular variable (e.g. the total number of radiolucent cavities present in all joint spaces) within the experiment and the second "1" refers to the pre-manipulation group. A similar process is then continued to generate a21 and a31. The reason for counting the number of radiolucent cavities not present (i.e. "No") was because no radiolucent cavities were demonstrated and the statistics program was not capable of comparing zero to zero for a significant difference.

TABLE 1.1 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE -MANIPULATION

	YES	NO	TOTAL
IN ALL JOINT SPACES		a11	10
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS		a21	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		a31	2

In Table 1.2, for example, a41 was generated as follows : the sum of the density readings of all ten joint spaces (C2-C7 bilaterally) for one subject was determined. This figure was divided by ten to determine the average joint density for that subject. Note that this average was later added to that of subject 2 which was determined in the same way and the sum of these was divided by the number of subjects in the experiment (i.e. two) to give the average pre-manipulation joint density value for one joint for the experimental group. This average value for the pre-manipulation group was recorded and was called a41. A similar procedure was used to determine a51, a61, a71, a81, a91 and the post-manipulation data (viz. a42, a52, a62, a72, a82, a92).

TABLE 1.2 : PRE-MANIPULATION

	MEAN
DENSITY READINGS OF ALL JOINT SPACES	a41
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS	a51
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION	a61
JOINT SPACE READINGS OF ALL JOINTS IN mm	a71
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm	a81
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION IN mm	a91

Table 1.3 was generated in a similar manner as Table 1.1

TABLE 1.3 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION

	YES	NO	TOTAL
IN ALL JOINT SPACES		a12	10
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS		a22	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		a32	2

Table 1.4 was generated in a similar manner as Table 1.2

TABLE 1.4 : POST-MANIPULATION

	MEAN
DENSITY READINGS OF ALL JOINT SPACES	a42
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS	a52
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION	a62
JOINT SPACE READINGS OF ALL JOINTS IN mm	a72
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm	a82
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION	a92

EXPERIMENT 2

Each subject's plain film X-ray provided two sets of data (i.e. pre-manipulation and post-manipulation). Visual examinations of the joint spaces before and after the manipulation were performed for the presence of radiolucent cavities and these were noted in Tables 2.1 and 2.4.

Each set of data included the left and right zygapophyseal joint space density readings and joint space widths of each joint from C2 to C7. Each set of data was averaged according to the criteria stipulated in Tables 2.2 and 2.4. The averages of the above for a single subject was again averaged to the corresponding data of the other subjects in this experiment.

Table 2.1 was generated in a similar manner as Table 1.1

TABLE 2.1 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION

	YES	NO	TOTAL
IN ALL JOINT SPACES		b11	10
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS		b21	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		b31	2
IN ALL JOINT SPACES + 8kg TRACTION		**b41**	**10**
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS + 8kg TRACTION		**b51**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**b61**	**2**

Table 2.2 was generated in a similar manner as Table 1.2

TABLE 2.2 : PRE-MANIPULATION

	MEAN
DENSITY READINGS OF ALL JOINT SPACES	b71
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS	b81
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION	b91
JOINT SPACE READINGS OF ALL JOINTS IN mm	b101
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm	b111
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION	b121
DENSITY READINGS OF ALL JOINT SPACES + 8kg TRACTION	**b131**
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS + 8kg TRACTION	**b141**
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION	**b151**
JOINT SPACE READINGS OF ALL JOINTS IN mm + 8kg TRACTION	**b161**
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm + 8kg TRACTION	**b171**
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION	**b181**

Table 2.3 was generated in a similar manner as Table 1.3

TABLE 2.3 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION

	YES	NO	TOTAL
IN ALL JOINT SPACES		b12	10
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS		b22	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		b32	2
IN ALL JOINT SPACES + 8kg TRACTION		**b42**	**10**
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS + 8kg TRACTION		**b52**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**b62**	**2**

Table 2.4 was generated in a similar manner as Table 1.4

TABLE 2.4 : POSTMANIPULATION

	MEAN
DENSITY READINGS OF ALL JOINT SPACES	b72
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS	b82
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION	b92
JOINT SPACE READINGS OF ALL JOINTS IN mm	b102
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm	b112
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION	b122
DENSITY READINGS OF ALL JOINT SPACES + 8kg TRACTION	**b132**
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS + 8kg TRACTION	**b142**
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION	**b152**
JOINT SPACE READINGS OF ALL JOINTS IN mm + 8kg TRACTION	**b162**
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm + 8kg TRACTION	**b172**
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION	**b182**

EXPERIMENT 3

Each subject's computed tomographic images provided two sets of data (i.e. pre-manipulation and post-manipulation). Visual examinations of the joint spaces before and after the manipulation were performed for the presence of radiolucent cavities and these were noted in Tables 3.1 and 3.3.

Each set of data included the left and right zygapophyseal joint space density readings and joint space widths of each joint from C2 to C5. Each set of data was averaged according to the criteria stipulated in Tables 3.2 and 3.4. The averages of the above for a single subject was again averaged to the corresponding data of the other subjects in the experiment.

In Experiments three, four, five and six the readings taken the joints at the segmental level of manipulation and adjacent levels refers to an average of six (i.e. the two joints at the level of manipulation - which was delivered to the C3-C4 segmental level, and the two joints above and below this level) joint spaces. The readings from the joints at the segmental level of manipulation refers to an average of two (i.e. the two joints at the level of manipulation) joint spaces. This manner of grouping the data was performed so that one may more accurately determine how the manipulation influences the joints at the segmental level of manipulation and adjacent levels, and just the joints at the segmental level of manipulation in terms of the variables used in this research. The whole cervical spine was not analyzed due to the risk of exposing the subjects to excessive radiation.

It must be noted that eight of the subjects that participated in Experiments one and two also participated in Experiments three and four.

Table 3.1 was generated in a similar manner as Table 1.1

TABLE 3.1 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION

	YES	NO	TOTAL
IN ALL JOINT SPACES		c11	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		c21	2
IN ALL JOINT SPACES + 5kg TRACTION		**c31**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 5kg TRACTION		**c41**	**2**

Table 3.2 was generated in a similar manner as Table 1.2

TABLE 3.2 : PRE-MANIPULATION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	c51
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	c61
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	c71
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	c81
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	c91
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	c101
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	c111
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	c121
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	c131
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	c141
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 5kg TRACTION	**c151**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c161**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 5kg TRACTION	**c171**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c181**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 5kg TRACTION	**c191**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c201**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 5kg TRACTION	**c211**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c221**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 5kg TRACTION	**c231**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c241**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	c251
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	c261
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 5kg TRACTION	**c271**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 5kg TRACTION	**c281**

Table 3.3 was generated in a similar manner as Table 1.3

TABLE 3.3 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION

	YES	NO	TOTAL
IN ALL JOINT SPACES		c12	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		c22	2
IN ALL JOINT SPACES + 5kg TRACTION		**c32**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 5kg TRACTION		**c42**	**2**

Table 3.4 was generated in a similar manner as Table 1.4

TABLE 3.4 : POST-MANIPULATION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	c52
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	c62
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	c72
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	c82
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	c92
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	c102
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	c112
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	c122
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	c132
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	c142
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 5kg TRACTION	**c152**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c162**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 5kg TRACTION	**c172**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c182**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 5kg TRACTION	**c192**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c202**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 5kg TRACTION	**c212**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c222**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 5kg TRACTION	**c232**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**c242**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	c252
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	c262
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 5kg TRACTION	**c272**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 5kg TRACTION	**c282**

EXPERIMENT 4

Table 4.1 was generated in a similar manner as Table 1.1

TABLE 4.1 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION + NECK FLEXION

	YES	NO	TOTAL
IN ALL JOINT SPACES		d11	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		d21	2
IN ALL JOINT SPACES + 8kg TRACTION		**d31**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**d41**	**2**

Table 4.2 was generated in a similar manner as Table 1.2

TABLE 4.2 : PRE-MANIPULATION + NECK FLEXION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	d51
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	d61
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	d71
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	d81
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	d91
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	d101
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	d111
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	d121
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	d131
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	d141
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 8kg TRACTION	**d151**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d161**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 8kg TRACTION	**d171**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d181**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**d191**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d201**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**d211**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d221**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 8kg TRACTION	**d231**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d241**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	d251
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	d261
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 8kg TRACTION	**d271**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 8kg TRACTION	**d281**

Table 4.3 was generated in a similar manner as Table 1.3

TABLE 4.3 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION + NECK FLEXION

	YES	NO	TOTAL
IN ALL JOINT SPACES		d12	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		d22	2
IN ALL JOINT SPACES + 8kg TRACTION		**d32**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**d42**	**2**

Table 4.4 was generated in a similar manner as Table 1.4

TABLE 4.4 : POST-MANIPULATION + NECK FLEXION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	d52
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	d62
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	d72
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	d82
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	d92
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	d102
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	d112
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	d122
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	d132
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	d142
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 8kg TRACTION	**d152**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d162**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 8kg TRACTION	**d172**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d182**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**d192**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d202**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**d212**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d222**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 8kg TRACTION	**d232**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**d242**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	d252
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	d262
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 8kg TRACTION	**d272**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 8kg TRACTION	**d282**

EXPERIMENT 5

Table 5.1 was generated in a similar manner as Table 1.1

TABLE 5.1 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION + LATERAL NECK FLEXION

	YES	NO	TOTAL
IN ALL JOINT SPACES		e11	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		e21	2
IN ALL JOINT SPACES + 8kg TRACTION		**e31**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**e41**	**2**

Table 5.2 was generated in a similar manner as Table 1.2

TABLE 5.2 : PRE-MANIPULATION + LATERAL NECK FLEXION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	e51
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	e61
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	e71
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	e81
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	e91
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	e101
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	e111
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	e121
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	e131
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	e141
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 8kg TRACTION	**e151**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e161**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 8kg TRACTION	**e171**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e181**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**e191**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e201**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**e211**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e221**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 8kg TRACTION	**e231**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e241**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	e251
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	e261
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 8kg TRACTION	**e271**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 8kg TRACTION	**e281**

Table 5.3 was generated in a similar manner as Table 1.3

TABLE 5.3 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION + LATERAL NECK FLEXION

	YES	NO	TOTAL
IN ALL JOINT SPACES		e12	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		e22	2
IN ALL JOINT SPACES + 8kg TRACTION		**e32**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**e42**	**2**

Table 5.4 was generated in a similar manner as Table 1.4

TABLE 5.4 : POST-MANIPULATION + LATERAL NECK FLEXION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	e52
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	e62
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	e72
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	e82
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	e92
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	e102
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	e112
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	e122
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	e132
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	e142
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 8kg TRACTION	**e152**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e162**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 8kg TRACTION	**e172**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e182**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**e192**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e202**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**e212**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e222**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 8kg TRACTION	**e232**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**e242**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	e252
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	e262
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 8kg TRACTION	**e272**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 8kg TRACTION	**e282**

EXPERIMENT 6

Table 6.1 was generated in a similar manner as Table 1.1

TABLE 6.1 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION

	YES	NO	TOTAL
IN ALL JOINT SPACES		f11	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		f21	2
IN ALL JOINT SPACES + 15kg TRACTION		**f31**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 15kg TRACTION		**f41**	**2**

Table 6.2 was generated in a similar manner as Table 1.2

TABLE 6.2 : PRE-MANIPULATION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	f51
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	f61
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	f71
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	f81
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	f91
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	f101
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	f111
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	f121
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	f131
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	f141
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 15kg TRACTION	**f151**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f161**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 15kg TRACTION	**f171**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f181**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 15kg TRACTION	**f191**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f201**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 15kg TRACTION	**f211**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f221**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 15kg TRACTION	**f231**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f241**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	f251
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	f261
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 15kg TRACTION	**f271**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 15kg TRACTION	**f281**

Table 6.3 was generated in a similar manner as Table 1.3

TABLE 6.3 : TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION

	YES	NO	TOTAL
IN ALL JOINT SPACES		f12	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		f22	2
IN ALL JOINT SPACES + 15kg TRACTION		**f32**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 15kg TRACTION		**f42**	**2**

Table 6.4 was generated in a similar manner as Table 1.4

TABLE 6.4 : POST-MANIPULATION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	f52
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	f62
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	f72
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	f82
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	f92
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	f102
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	f112
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	f122
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	f132
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	f142
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 15kg TRACTION	**f152**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f162**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 15kg TRACTION	**f172**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f182**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 15kg TRACTION	**f192**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f202**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 15kg TRACTION	**f212**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f222**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 15kg TRACTION	**f232**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**f242**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	f252
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	f262
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 15kg TRACTION	**f272**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 15kg TRACTION	**f282**

EXPERIMENTS 3+4+5+6

In this group the averages of selected variables in Experiments three, four, five and six were added together and divided by four. For example, the average pixel intensity value of all joint spaces (i.e. C2-C5 bilaterally) in Experiment Three (c51) was added to the corresponding variables in Experiments Four (d51), Five (e51) and Six (f51) and divided by four to give a new average for this variable with a larger sample size. This new average was renamed v11. The "v" stands for the combined group, the first "1" stands for the variable under examination and the second "1" stands for the pre-manipulation group.

The data relating to the number of radiolucent cavities visualized was not included in the combined group because none were demonstrated in any of the Experimental groups. The maximum pixel intensity values were not included in this group because the emphasis of this study was on demonstrating gas in the joint space. The maximum pixel intensity value indicates the nature of the most dense structure present within the area encircled using the computer's software.

TABLE 7.1 : PRE-MANIPULATION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	c51 + d51 + e51 + f51 = v11
AVERAGE PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL	c61 + d61 + e61 + f61 = v21
MINIMUM PIXEL INTENSITY OF ALL JOINT SPACES	c91 + d91 + e91 + f91 = v151
MINIMUM PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL	c101 + d101 + e101 + f101 = v161
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	c131 + d131 + e131 + f131 = v51
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT C3-C4 LEVEL	c141 + d141 + e141 + f141 = v61
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + TRACTION	**c151 + d151 + e151 + f151 = v31**
AVERAGE PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL + TRACTION	**c161 + d161 + e161 + f161 = v41**
MINIMUM PIXEL INTENSITY OF ALL JOINT SPACES + TRACTION	**c191 + d191 + e191 + f191 = v131**
MINIMUM PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL + TRACTION	**c201 + d201 + e201 + f201 = v141**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + TRACTION	**c231 + d231 + e231 + f231 = v71**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT C3-C4 LEVEL + TRACTION	**c241 + d241 + e241 + f241 = v81**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN MILLIMETERS	c251 + d251 + e251 + f251 = v91
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 LEVEL IN MILLIMETERS	c261 + d261 + f261 + f261 = v101
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN MILLIMETERS + TRACTION	**c271 + d271 + e271 + f271 = v111**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 LEVEL IN MILLIMETERS + TRACTION	**c281 + d281 + e281 + f281 = v121**

The data in Table 7.2 was generated in a similar manner as Table 7.1

TABLE 7.2 : POST-MANIPULATION

	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	c52 + d52 + e52 + f52 = v12
AVERAGE PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL	c62 + d62 + e62 + f62 = v22
MINIMUM PIXEL INTENSITY OF ALL JOINT SPACES	c92 + d92 + e92 + f92 = v152
MINIMUM PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL	c102 + d102 + e102 + f102 = v162
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	c132 + d132 + e132 + f132 = v52
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT C3-C4 LEVEL	c142 + d142 + e142 + f142 = v62
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + TRACTION	**c152 + d152 + e152 + f152 = v32**
AVERAGE PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL + TRACTION	**c162 + d162 + e162 + f162 = v42**
MINIMUM PIXEL INTENSITY OF ALL JOINT SPACES + TRACTION	**c192 + d192 + e192 + f192 = v132**
MINIMUM PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL + TRACTION	**c202 + d202 + e202 + f202 = v142**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + TRACTION	**c232 + d232 + e232 + f232 = v72**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT C3-C4 LEVEL + TRACTION	**c242 + d242 + e242 + f242 = v82**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN MILLIMETERS	c252 + d252 + e252 + f252 = v92
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 LEVEL IN MILLIMETERS	c262 + d262 + f262 + f262 = v102
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN MILLIMETERS + TRACTION	**c272 + d272 + e272 + f272 = v112**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 LEVEL IN MILLIMETERS + TRACTION	**c282 + d282 + e282 + f282 = v122**

3.7 The Interpretation of the Data.

16 Mann-Whitney U tests were performed comparing :

- v11 to v12 (average pixel intensity of all joint spaces)
- v21 to v22 (average pixel intensity of joint spaces at the C3-C4)
- v31 to v32 (average pixel intensity of all joint spaces + traction)
- v41 to v42 (average pixel intensity of joint spaces at the C3-C4 level + traction)
- v51 to v52 (total defined area in millimeters squared of all joint spaces)
- v61 to v62 (total defined area in millimeters squared of joint spaces at C3-C4 level)
- v71 to v72 (total defined area in millimeters squared of all joint spaces + traction)
- v81 to v82 (total defined area in millimeters squared of joint spaces at C3-C4 level + traction)
- v91 to v92 (joint space readings of all the joint spaces in millimeters)
- v101 to v102 (joint space readings of the joint spaces at the C3-C4 level in millimeters)
- v111 to v112 (joint space readings of all the joint spaces in millimeters + traction)
- v121 to v122 (joint space readings of the joint spaces at the C3-C4 level in millimeters + traction)
- v131 to v132 (minimum pixel intensity of all joint spaces + traction)
- v141 to v142 (minimum pixel intensity of joint spaces at the C3-C4 level + traction)
- v151 to v152 (minimum pixel intensity of all joint spaces)
- v161 to v162 (minimum pixel intensity of joint spaces at the C3-C4 level)

16 Sign Ranked Wilcoxon Tests were performed between the pre-manipulation data of experiment group 5 and experiment group 6 as follows :

- e51 to f51 (average pixel intensity of all joint spaces)
- e61 to f61 (average pixel intensity of joint spaces at the C3-C4 level)
- e91 to f91 (minimum pixel intensity of all joint spaces)
- e101 to f101 (minimum pixel intensity of joint spaces at the C3-C4 level)
- e131 to f131 (total defined area in millimeters squared of all joint spaces)
- e141 to f141 (total defined area in millimeters squared of joint spaces at C3-C4 level)
- e151 to f151 (average pixel intensity of all joint spaces + traction)
- e161 to f161 (average pixel intensity of joint spaces at the C3-C4 level + traction)
- e191 to f191 (minimum pixel intensity of all joint spaces + traction)
- e201 to f201 (minimum pixel intensity of joint spaces at the C3-C4 level + traction)
- e231 to f231 (total defined area in millimeters squared of all joint spaces + traction)
- e241 to f241 (total defined area in millimeters squared of joint spaces at C3-C4 level + traction)
- e251 to f251 (joint space readings of all the joint spaces in millimeters)
- e261 to f261 (joint space readings of the joint spaces at the C3-C4 level in millimeters)
- e271 to f271 (joint space readings of all the joint spaces in millimeters + traction)
- e281 to f281 (joint space readings of the joint spaces at the C3-C4 level in millimeters + traction)

16 Sign Ranked Wilcoxon Tests were performed between the post-manipulation data of experiment group 5 and experiment group 6 as follows :

- e52 to f52 (average pixel intensity of all joint spaces)
- e62 to f62 (average pixel intensity of joint spaces at the C3-C4 level)
- e92 to f92 (minimum pixel intensity of all joint spaces)
- e102 to f102 (minimum pixel intensity of joint spaces at the C3-C4 level)
- e132 to f132 (total defined area in millimeters squared of all joint spaces)
- e142 to f142 (total defined area in millimeters squared of joint spaces at C3-C4 level)
- e152 to f152 (average pixel intensity of all joint spaces + traction)
- e162 to f162 (average pixel intensity of joint spaces at the C3-C4 level + traction)
- e192 to f192 (minimum pixel intensity of all joint spaces + traction)
- e202 to f202 (minimum pixel intensity of joint spaces at the C3-C4 level + traction)
- e232 to f232 (total defined area in millimeters squared of all joint spaces + traction)
- e242 to f242 (total defined area in millimeters squared of joint spaces at C3-C4 level + traction)
- e252 to f252 (joint space readings of all the joint spaces in millimeters)
- e262 to f262 (joint space readings of the joint spaces at the C3-C4 level in millimeters)
- e272 to f272 (joint space readings of all the joint spaces in millimeters + traction)
- e282 to f282 (joint space readings of the joint spaces at the C3-C4 level in millimeters + traction)

In addition to the above, Mann-Whitney U Tests were performed on each experiment group as follows :

EXPERIMENT 1

- a11 to a12
- a21 to a22
- a31 to a32
- a41 to a42
- a51 to a52
- a61 to a62
- a71 to a72
- a81 to a82
- a91 to a92

EXPERIMENT 2

- b11 to b12
- b21 to b22
- b31 to b32
- b41 to b42
- b51 to b52
- b61 to b62
- b71 to b72
- b81 to b82
- b91 to b92
- b101 to b102
- b111 to b112
- b121 to b122
- b131 to b132
- b141 to b142
- b151 to b152
- b161 to b162
- b171 to b172
- b181 to b182

EXPERIMENT 3

- c11 to c12
- c21 to c22
- c31 to c32
- c41 to c42
- c51 to c52
- c61 to c62
- c71 to c72
- c81 to c82
- c91 to c92
- c101 to c102
- c111 to c112
- c121 to c122
- c131 to c132
- c141 to c142
- c151 to c152
- c161 to c162
- c171 to c172
- c181 to c182
- c191 to c192
- c201 to c202
- c211 to c212
- c221 to c222
- c231 to c232
- c241 to c242
- c251 to c252
- c261 to c262
- c271 to c272
- c281 to c282

EXPERIMENT 4

- d11 to d12
- d21 to d22
- d31 to d32
- d41 to d42
- d51 to d52
- d61 to d62
- d71 to d72
- d81 to d82
- d91 to d92
- d101 to d102
- d111 to d112
- d121 to d122
- d131 to d132
- d141 to d142
- d151 to d152
- d161 to d162
- d171 to d172
- d181 to d182
- d191 to d192
- d201 to d202
- d211 to d212
- d221 to d222
- d231 to d232
- d241 to d242
- d251 to d252
- d261 to d262
- d271 to d272
- d281 to d282

EXPERIMENT 5

- e11 to e12
- e21 to e22
- e31 to e32
- e41 to e42
- e51 to e52
- e61 to e62
- e71 to e72
- e81 to e82
- e91 to e92
- e101 to e102
- e111 to e112
- e121 to e122
- e131 to e132
- e141 to e142
- e151 to e152
- e161 to e162
- e171 to e172
- e181 to e182
- e191 to e192
- e201 to e202
- e211 to e212
- e221 to e222
- e231 to e232
- e241 to e242
- e251 to e252
- e261 to e262
- e271 to e272
- e281 to e282

EXPERIMENT 6

- f11 to f12
- f21 to f22
- f31 to f32
- f41 to f42
- f51 to f52
- f61 to f62
- f71 to f72
- f81 to e82
- f91 to f92
- f101 to f102
- f111 to f112
- f121 to f122
- f131 to f132
- f141 to f142
- f151 to f152
- f161 to f162
- f171 to f172
- f181 to f182
- f191 to f192
- f201 to f202
- f211 to f212
- f221 to f222
- f231 to f232
- f241 to f242
- f251 to f252
- f261 to f262
- f271 to f272
- f281 to f282

CHAPTER 4

THE RESULTS

4.1 The criteria for the admissibility of the data

- Data was only taken from the recordings following the manipulations performed in the presence of the researcher.
- Data of the recordings was only used if audible cavitations were heard during the manipulation.

4.2 Demographic Data

Table 8.1: Age distribution

	Exp. 3+4+5+6	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6
AGE RANGE	20-29	23-24	22-24	22-24	22-24	20-24	23-29
AVERAGE AGE	23.04	23.50	22.88	22.75	23.14	22.00	24.20

Table 8.2: Race Distribution

	Exp. 3+4+5+6	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6
WHITE	20	2	8	4	6	5	5
INDIAN	1	0	0	0	1	0	0

Table 8.3: Sex Distribution

	Exp. 3+4+5+6	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6
MALE	15	1	6	3	4	4	4
FEMALE	6	1	2	1	3	1	1

4.3 OBJECTIVE 1

Table 9 : Experiments 3+4+5+6

PRE-MANIPULATION	*MEAN*
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	482.36
AVERAGE PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL	490.45
MINIMUM PIXEL INTENSITY OF ALL JOINT SPACES	318.45
MINIMUM PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL	309.29
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	24.86
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT C3-C4 LEVEL	27.31
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + TRACTION	**491.78**
AVERAGE PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL + TRACTION	**486.75**
MINIMUM PIXEL INTENSITY OF ALL JOINT SPACES + TRACTION	**320.74**
MINIMUM PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL + TRACTION	**321.03**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + TRACTION	**27.48**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT C3-C4 LEVEL + TRACTION	**29.10**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN MILLIMETERS	2.40
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 LEVEL IN MILLIMETERS	2.38
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN MILLIMETERS + TRACTION	**2.41**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 LEVEL IN MILLIMETERS + TRACTION	**2.38**

Table 10 : Experiment 1

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION	YES	NO	TOTAL
IN ALL JOINT SPACES		10	10
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2

PRE-MANIPULATION	MEAN
DENSITY READINGS OF ALL JOINT SPACES	1.71
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS	1.91
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION	2.05
JOINT SPACE READINGS OF ALL JOINTS IN mm	2.82
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm	2.81
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION	2.98

Table 11 : Experiment 2

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION	**YES**	**NO**	**TOTAL**
IN ALL JOINT SPACES		10	10
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 8kg TRACTION		**10**	**10**
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS + 8kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**2**	**2**

PRE-MANIPULATION	**MEAN**
DENSITY READINGS OF ALL JOINT SPACES	1.18
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS	1.17
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION	1.21
JOINT SPACE READINGS OF ALL JOINTS IN mm	2.60
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm	2.69
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION	2.54
DENSITY READINGS OF ALL JOINT SPACES + 8kg TRACTION	**1.04**
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS + 8kg TRACTION	**1.07**
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION	**1.12**
JOINT SPACE READINGS OF ALL JOINTS IN mm + 8kg TRACTION	**2.60**
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm + 8kg TRACTION	**2.69**
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION	**2.54**

Table 12 : Experiment 3

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PREMANIPULATION	**YES**	**NO**	**TOTAL**
IN ALL JOINT SPACES		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 5kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 5kg TRACTION		**2**	**2**

PRE-MANIPULATION	**MEAN**
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	476.84
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	512.00
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	82.42
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	80.28
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	314.83
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	311.63
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	713.67
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	708.00
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	17.08
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	17.75
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 5kg TRACTION	**508.00**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**509.83**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 5kg TRACTION	**90.65**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**128.17**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 5kg TRACTION	**321.39**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**336.44**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 5kg TRACTION	**759.58**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**798.50**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 5kg TRACTION	**21.64**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**23.83**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	2.09
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	2.01
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 5kg TRACTION	**1.98**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 5kg TRACTION	**1.88**

Table 13 : Experiment 4

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION + NECK FLEXION	YES	NO	TOTAL
IN ALL JOINT SPACES		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 8kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**2**	**2**

PRE-MANIPULATION + NECK FLEXION	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	481.74
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	479.07
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	61.55
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	60.84
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	344.90
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	341.64
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	640.02
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	644.14
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	25.12
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	28.93
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 8kg TRACTION	**491.10**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**479.00**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 8kg TRACTION	**72.21**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**69.80**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**323.93**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**318.43**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**697.86**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**684.57**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 8kg TRACTION	**27.25**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**29.43**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	2.55
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	2.56
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 8kg TRACTION	**2.55**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 8kg TRACTION	**2.56**

Table 14: Experiment 5

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION + LATERAL NECK FLEXION	**YES**	**NO**	**TOTAL**
IN ALL JOINT SPACES		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 8kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**2**	**2**

PRE-MANIPULATION + LATERAL NECK FLEXION	**MEAN**
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	482.33
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	495.00
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	72.33
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	69.46
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	314.70
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	317.00
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	657.50
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	667.10
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	24.20
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	25.90
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 8kg TRACTION	**485.33**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**480.20**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 8kg TRACTION	**67.56**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**67.46**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**329.60**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**341.00**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**649.63**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**651.30**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 8kg TRACTION	**17.13**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**23.20**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	2.42
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	2.42
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 8kg TRACTION	**2.42**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 8kg TRACTION	**2.42**

Table 15: Experiment 6

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : PRE-MANIPULATION	YES	NO	TOTAL
IN ALL JOINT SPACES		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 15kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 15kg TRACTION		**2**	**2**

PRE-MANIPULATION	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	487.67
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	484.60
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	81.40
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	87.86
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	288.07
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	254.40
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	696.57
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	691.50
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	31.37
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	34.10
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 15kg TRACTION	**489.47**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**490.30**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 15kg TRACTION	**80.63**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**79.51**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 15kg TRACTION	**307.03**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**305.90**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 15kg TRACTION	**700.90**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**688.00**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 15kg TRACTION	**35.60**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**28.41**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	2.40
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	2.40
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 15kg TRACTION	**2.40**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 15kg TRACTION	**2.40**

4.4 OBJECTIVE 2

Table 16: Experiments 3+4+5+6

POST-MANIPULATION	*MEAN*
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	491.08
AVERAGE PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL	484.07
MINIMUM PIXEL INTENSITY OF ALL JOINT SPACES	328.33
MINIMUM PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL	318.60
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	25.86
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT C3-C4 LEVEL	26.52
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + TRACTION	**483.31**
AVERAGE PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL + TRACTION	**476.29**
MINIMUM PIXEL INTENSITY OF ALL JOINT SPACES + TRACTION	**315.29**
MINIMUM PIXEL INTENSITY OF JOINT SPACES AT THE C3-C4 LEVEL + TRACTION	**308.12**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + TRACTION	**27.52**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT C3-C4 LEVEL + TRACTION	**28.79**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN MILLIMETERS	2.43
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 LEVEL IN MILLIMETERS	2.45
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN MILLIMETERS + TRACTION	**2.41**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 LEVEL IN MILLIMETERS + TRACTION	**2.40**

Table 17: Experiment 1

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION	YES	NO	TOTAL
IN ALL JOINT SPACES		10	10
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2

POST-MANIPULATION	MEAN
DENSITY READINGS OF ALL JOINT SPACES	1.78
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS	1.95
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION	2.11
JOINT SPACE READINGS OF ALL JOINTS IN mm	2.82
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm	2.81
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION	2.98

Table 18: Experiment 2

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION	**YES**	**NO**	**TOTAL**
IN ALL JOINT SPACES		10	10
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 8kg TRACTION		**10**	**10**
IN JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS + 8kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**2**	**2**

POSTMANIPULATION	**MEAN**
DENSITY READINGS OF ALL JOINT SPACES	1.11
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS	1.12
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION	1.15
JOINT SPACE READINGS OF ALL JOINTS IN mm	2.60
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm	2.70
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION	2.53
DENSITY READINGS OF ALL JOINT SPACES + 8kg TRACTION	**1.18**
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS + 8kg TRACTION	**1.23**
DENSITY READINGS OF ALL JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION	**1.30**
JOINT SPACE READINGS OF ALL JOINTS IN mm + 8kg TRACTION	**2.64**
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION AND ADJACENT LEVELS IN mm + 8kg TRACTION	**2.77**
JOINT SPACE READINGS OF JOINTS AT SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION	**2.61**

Table 19: Experiment 3

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION	YES	NO	TOTAL
IN ALL JOINT SPACES		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 5kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 5kg TRACTION		**2**	**2**

POST-MANIPULATION	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	482.54
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	471.38
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	78.30
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	76.63
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	314.21
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	293.38
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	714.13
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	706.63
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	18.29
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	19.00
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 5kg TRACTION	**454.75**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**443.00**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 5kg TRACTION	**73.90**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**80.79**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 5kg TRACTION	**283.73**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**287.13**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 5kg TRACTION	**686.98**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**695.13**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 5kg TRACTION	**20.28**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 5kg TRACTION	**19.50**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	**2.10**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	**2.05**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 5kg TRACTION	**2.09**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 5kg TRACTION	**2.01**

Table 20: Experiment 4

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POSTMANIPULATION + NECK FLEXION	YES	NO	TOTAL
IN ALL JOINT SPACES		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 8kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**2**	**2**

POST-MANIPULATION + NECK FLEXION	MEAN
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	487.02
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	477.86
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	60.70
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	56.59
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	338.00
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	321.43
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	642.93
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	630.57
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	25.33
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	24.79
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 8kg TRACTION	**477.86**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**475.07**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 8kg TRACTION	**62.40**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**59.41**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**321.67**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**320.64**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**647.26**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**642.43**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 8kg TRACTION	**28.27**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**30.79**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	2.55
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	2.56
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 8kg TRACTION	**2.55**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 8kg TRACTION	**2.56**

Table 21: Experiment 5

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POSTMANIPULATION + LATERAL NECK FLEXION	**YES**	**NO**	**TOTAL**
IN ALL JOINT SPACES		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 8kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 8kg TRACTION		**2**	**2**

POST-MANIPULATION + LATERAL NECK FLEXION	**MEAN**
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	492.93
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	493.90
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	74.89
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	73.11
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	336.73
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	349.90
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	682.53
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	688.30
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	22.83
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	22.90
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 8kg TRACTION	**487.97**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**473.70**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 8kg TRACTION	**103.37**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**77.67**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**326.60**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**320.00**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 8kg TRACTION	**697.33**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**687.40**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 8kg TRACTION	**23.70**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 8kg TRACTION	**25.50**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	2.42
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	2.42
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 8kg TRACTION	**2.42**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 8kg TRACTION	**2.42**

Table 22 : Experiment 6

TOTAL NUMBER OF RADIOLUCENT CAVITIES PRESENT : POST-MANIPULATION	**YES**	**NO**	**TOTAL**
IN ALL JOINT SPACES		6	6
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION		2	2
IN ALL JOINT SPACES + 15kg TRACTION		**6**	**6**
IN THE JOINT SPACES AT THE SEGMENTAL LEVEL OF MANIPULATION + 15kg TRACTION		**2**	**2**

POST-MANIPULATION	**MEAN**
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES	501.73
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL	493.10
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES	81.10
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	82.06
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	317.70
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	303.50
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES	721.45
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	716.80
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES	35.68
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL	38.60
AVERAGE PIXEL INTENSITY OF ALL JOINT SPACES + 15kg TRACTION	**509.13**
AVERAGE PIXEL INTENSITY AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**507.20**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF ALL JOINT SPACES + 15kg TRACTION	**80.97**
STANDARD DEVIATION OF PIXEL INTENSITY VALUES OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**84.83**
MINIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 15kg TRACTION	**320.30**
MINIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**295.50**
MAXIMUM PIXEL INTENSITY VALUE OF ALL JOINT SPACES + 15kg TRACTION	**725.33**
MAXIMUM PIXEL INTENSITY VALUE OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**714.30**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF ALL JOINT SPACES + 15kg TRACTION	**36.07**
TOTAL DEFINED AREA IN MILLIMETERS SQUARED OF JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL + 15kg TRACTION	**36.70**
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm	2.55
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm	2.65
JOINT SPACE READINGS OF ALL THE JOINT SPACES IN mm + 15kg TRACTION	**2.47**
JOINT SPACE READINGS OF THE JOINT SPACES AT THE C3-C4 VERTEBRAL LEVEL IN mm + 15kg TRACTION	**2.48**

4.5 OBJECTIVE 3

The third objective was to compare the data obtained from before the manipulation to that obtained after the manipulation utilizing Mann-Whitney U tests in order to determine if significant alterations occur in terms of joint space size and density. Wilcoxon Signed Rank tests were also performed to compare the pre-manipulative data of Experiments 5 and 6 to the corresponding post-manipulative data.

It is important to note that the author observed that when using either the Vernier calipers or the CT software to measure the same joint space on different occasions, the difference in measurement between these occasions varied no more than 0.1 millimeter.

4.5.1 RESULTS OF THE MANN-WHITNEY U TESTS

All tests comparing the pre-manipulation data of Experiments 3+4+5+6 to the post-manipulation data of Experiments 3+4+5+6 indicated that no significant differences were present at the 5% level of significance.

All tests comparing the pre-manipulation data of Experiments 1-6 to the post-manipulation data of Experiments 1-6 respectively indicated that no significant differences were present at the 5% level of significance, except for the following :

- b141 to b142 (Density readings of the joint spaces at the segmental level manipulation and adjacent levels + 8kg traction); (p=0.042).
- b151 to b152 (Density readings of the joint spaces at the segmental level manipulation + 8kg traction); (p=0.037).

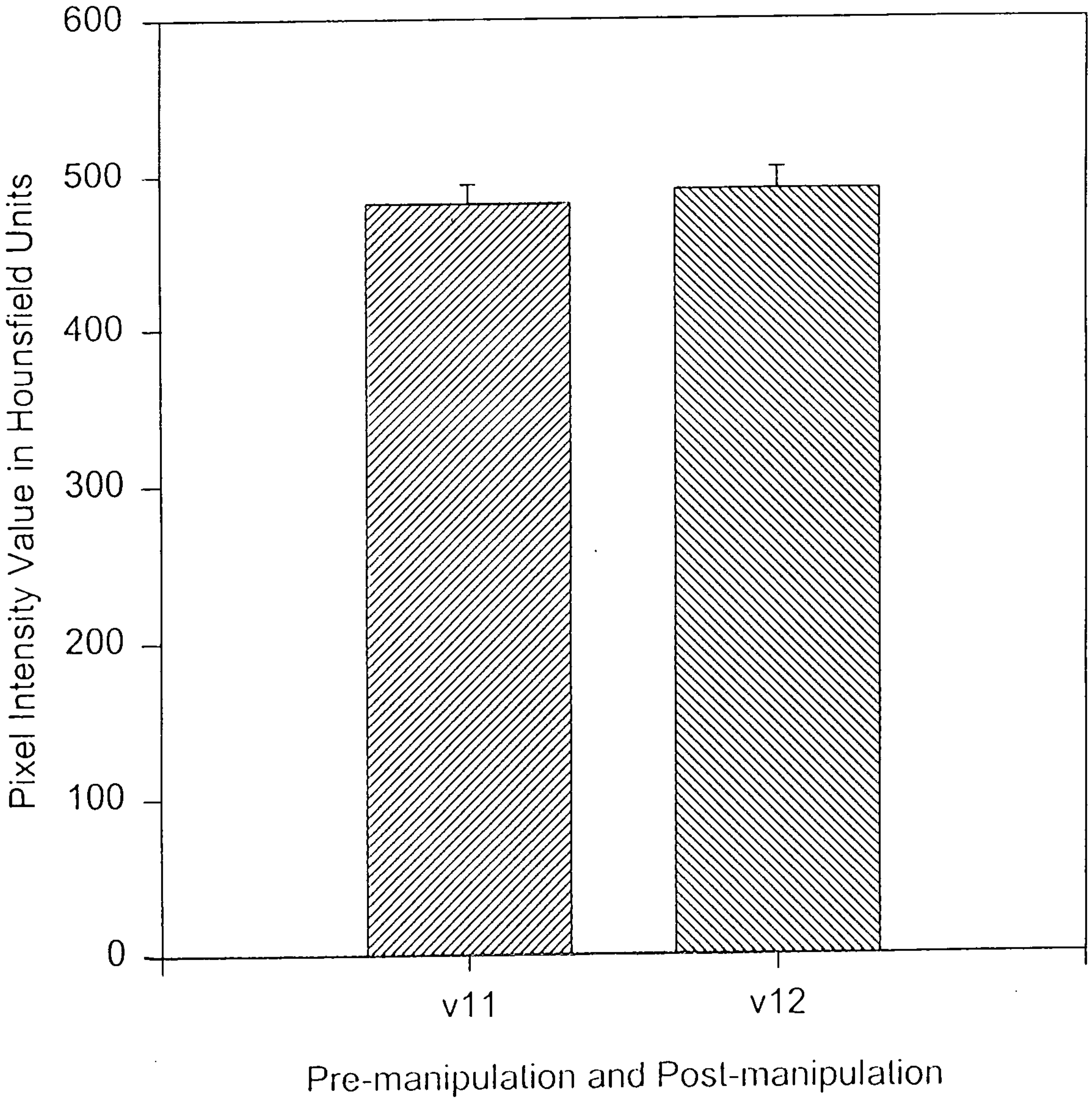
4.5.2 RESULTS OF THE WILCOXON RANK SIGNED TESTS

Due to varying sample sizes between experimental groups, only a comparison between Experiment 5 (5 subjects) and Experiment 6 (5 subjects) could be made. Note that all the pre-manipulation data was considered as the control data and although it was compared to data from another experimental group it was still considered intra-group data. In a similar manner all post-manipulation data was considered as the experimental data which was also compared as intra-group data.

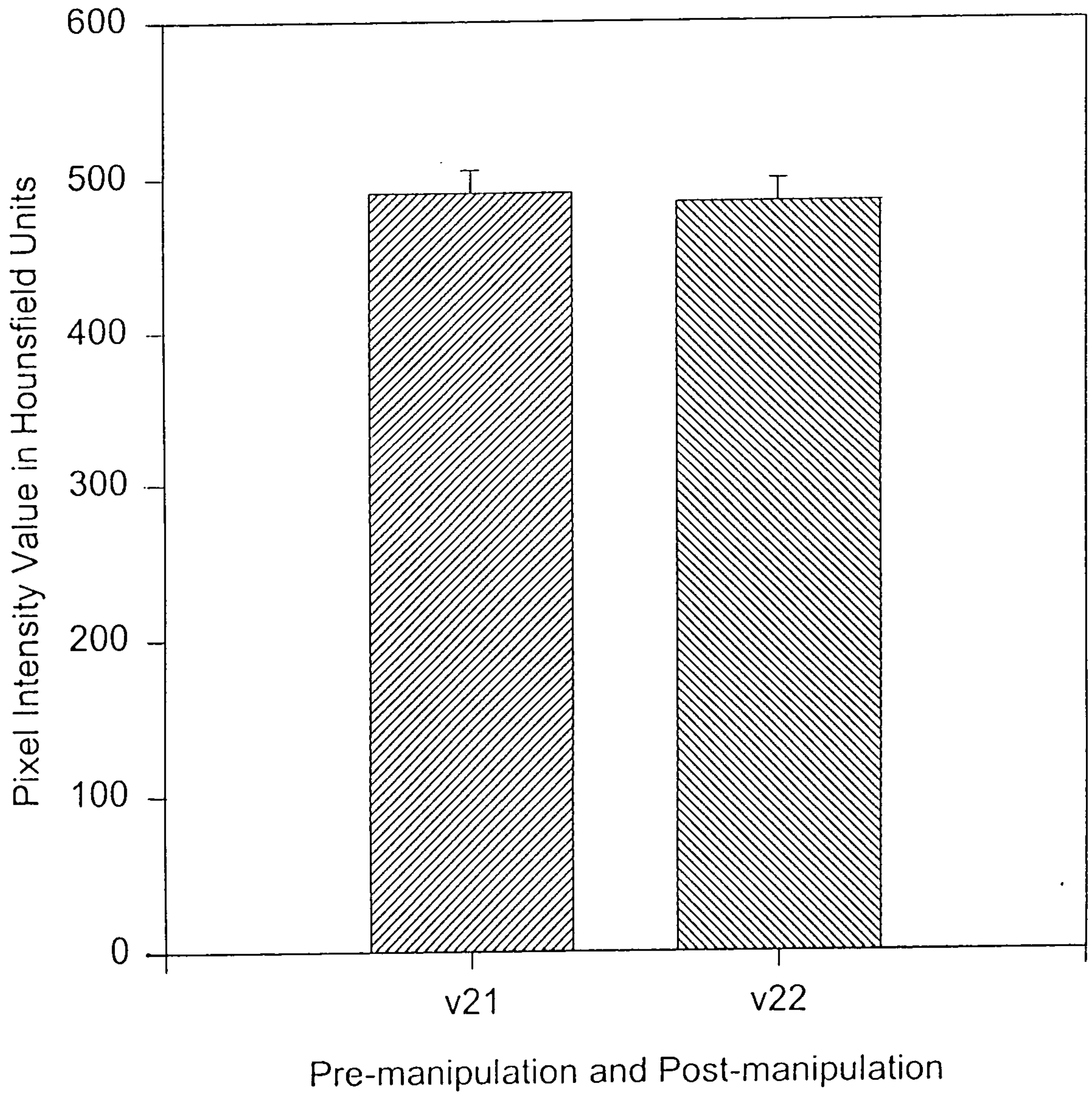
All tests comparing the pre-manipulation data of Experiment 5 to the pre-manipulation data of Experiment 6 indicated that no significant differences were present at the 5% level of significance. All tests comparing the post-manipulation data of Experiment 5 to the post-manipulation data of Experiment 6 indicated that no significant differences were present at the 5% level of significance.

The following bar graphs compare the pre-manipulation data of Experiments 3+4+5+6 to the post-manipulation data of Experiments 3+4+5+6.

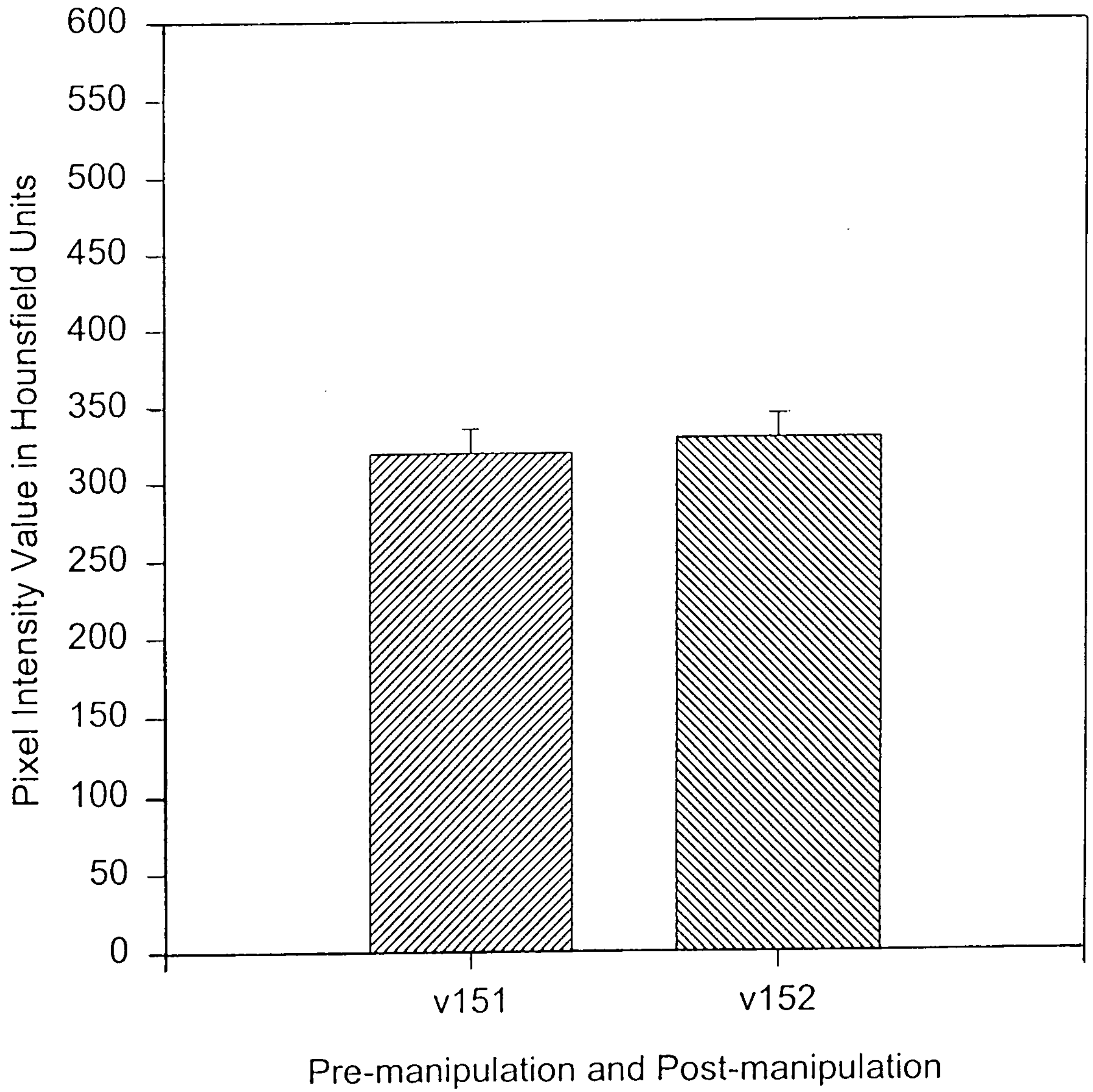
Graph 1: Average Pixel Intensity Value of all Joint Spaces



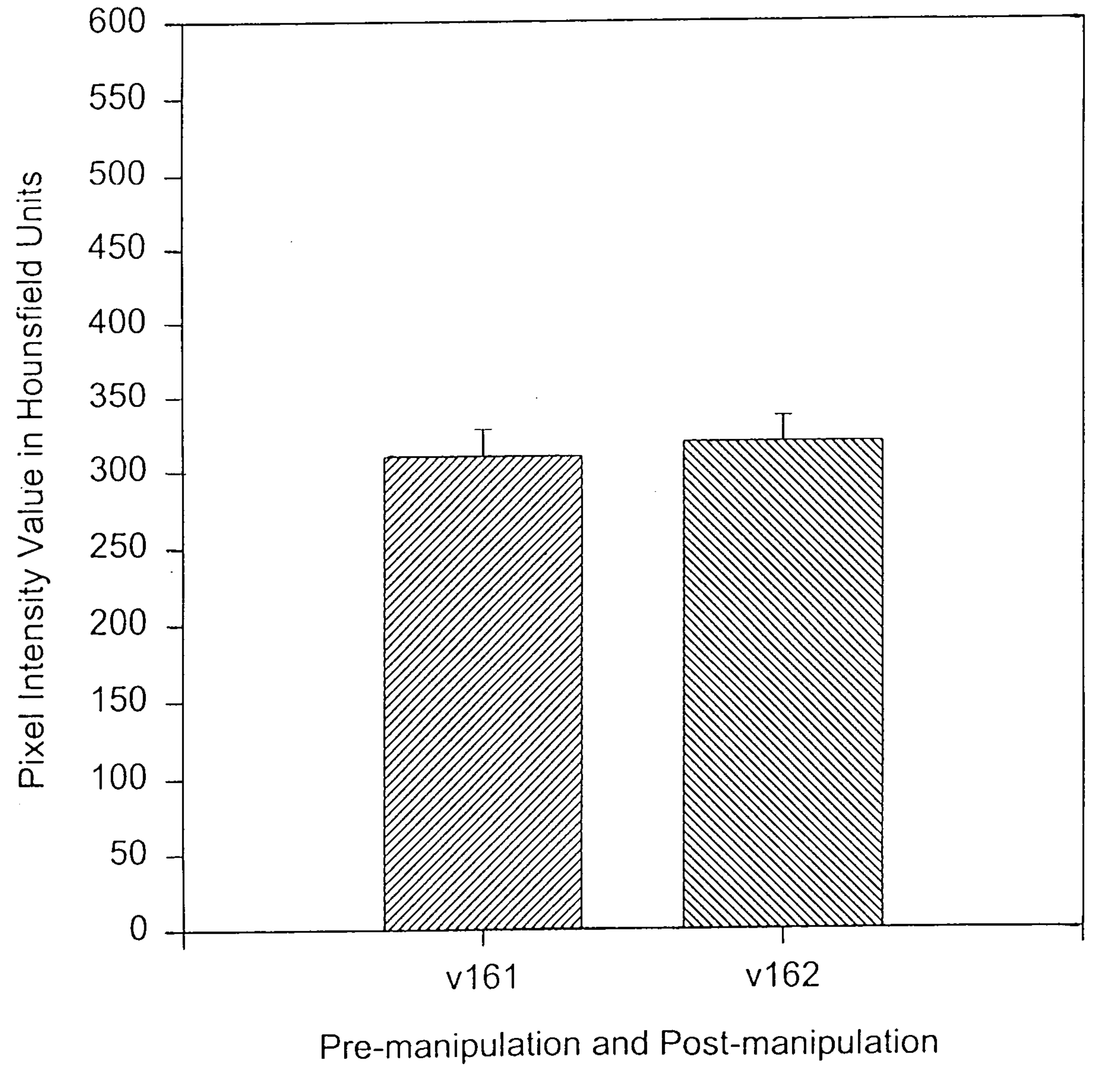
Graph 2: Average Pixel Intensity Value of the Joint Spaces at the C3-C4 Level



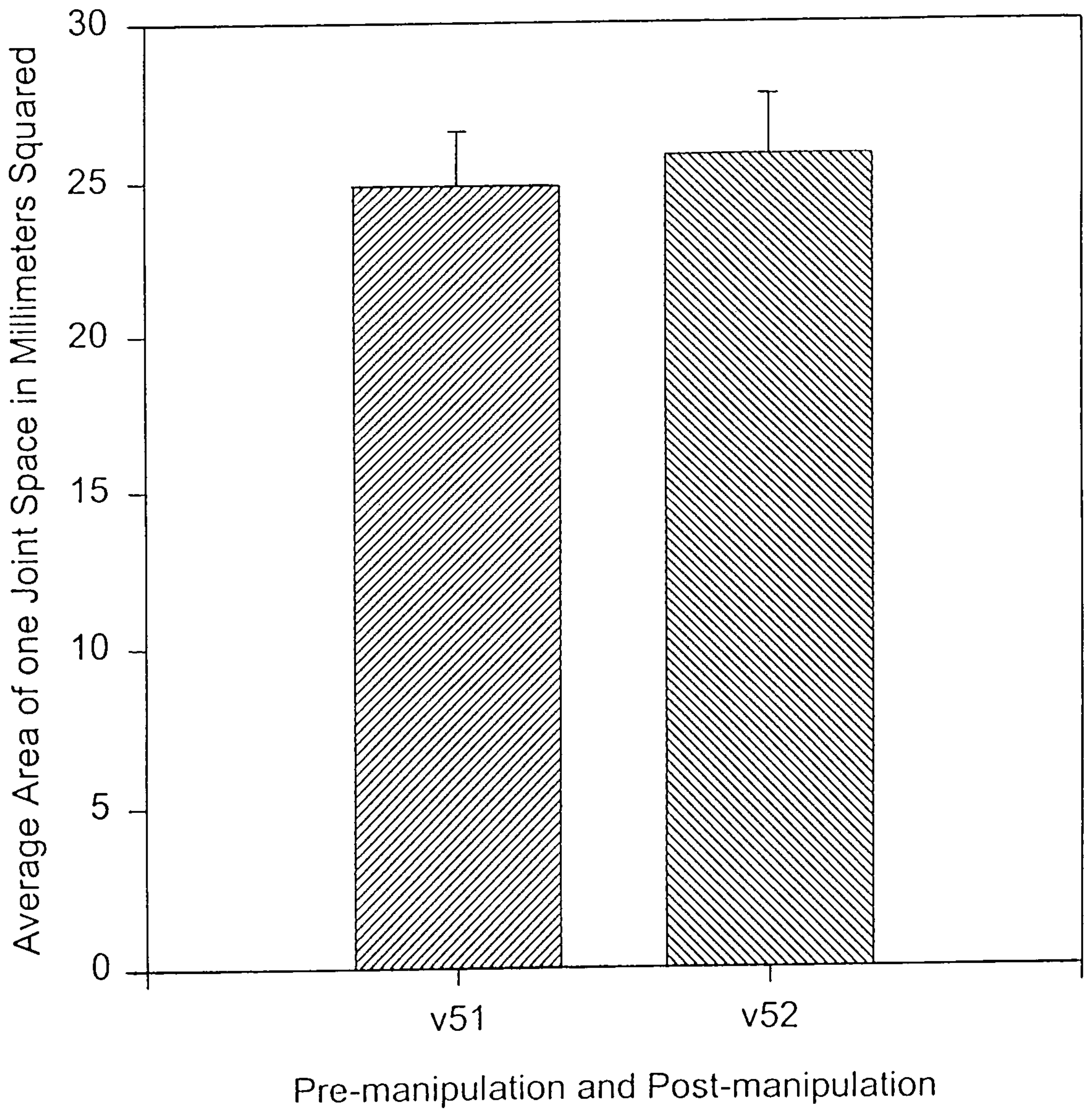
Graph 3: Minimum Pixel Intensity Value of all Joint Spaces



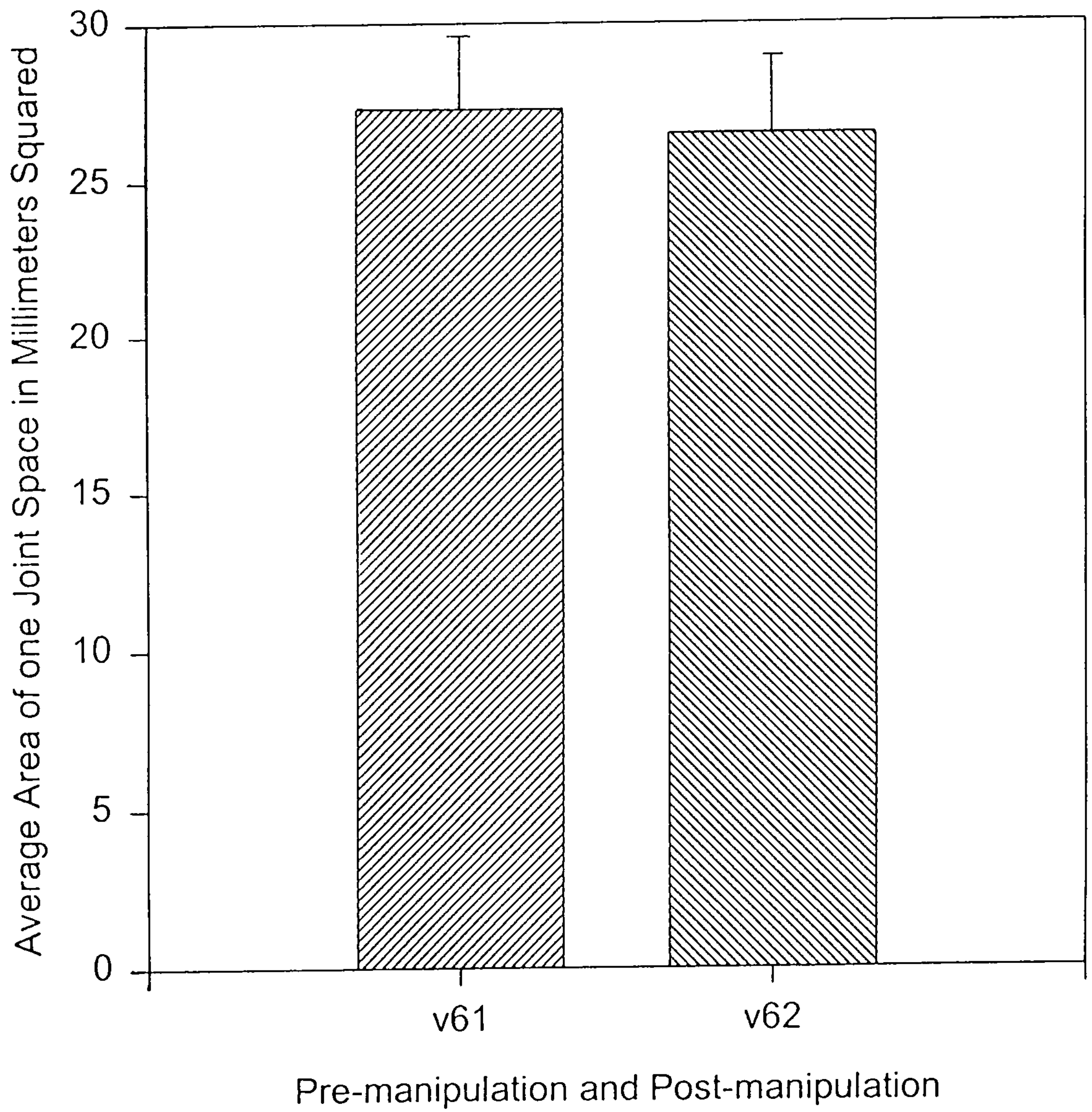
Graph 4: Minimum Pixel Intensity of the Joint Spaces at the C3-C4 Level



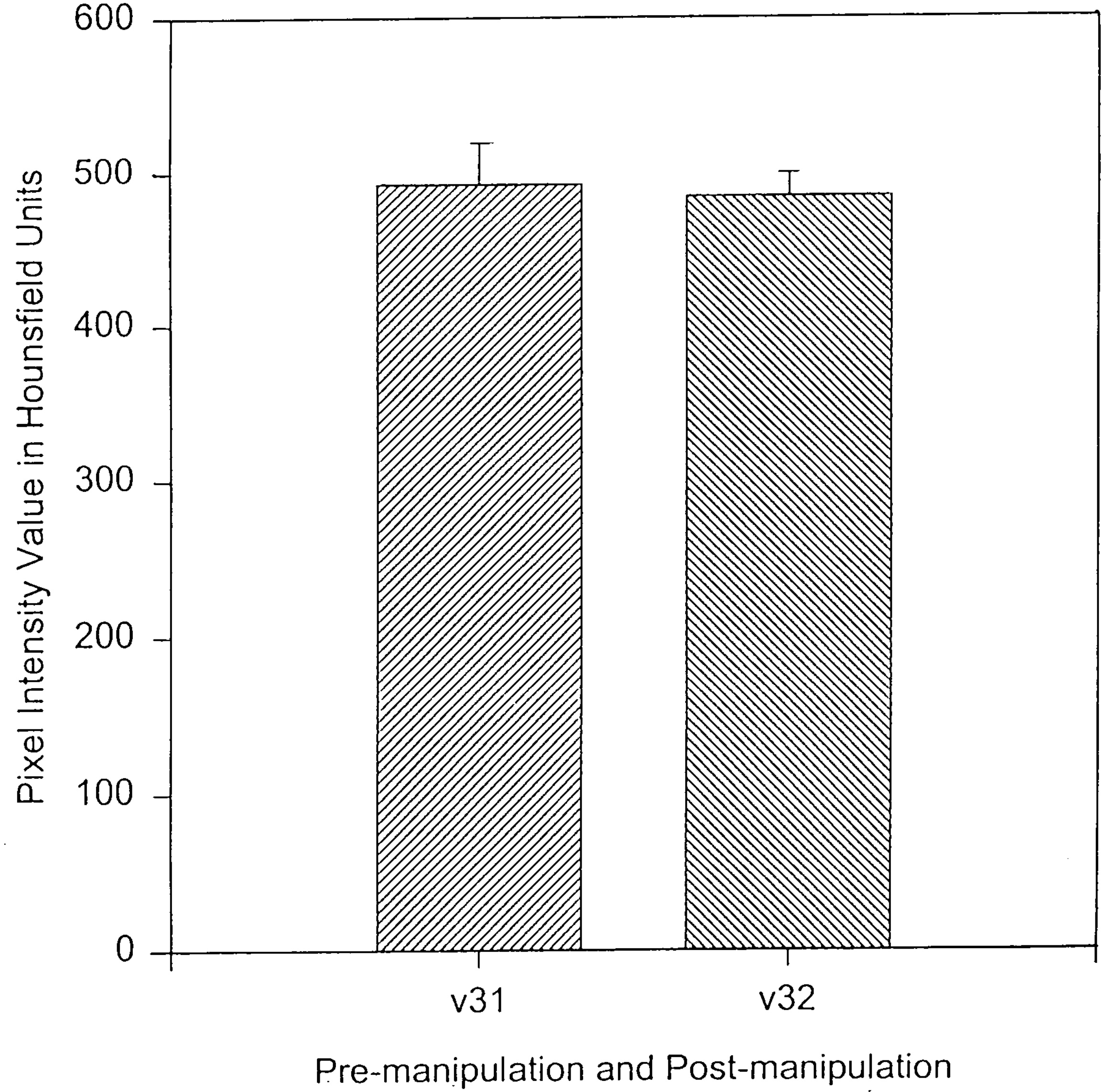
Graph 5: Average Total Defined Area of all Joint Spaces



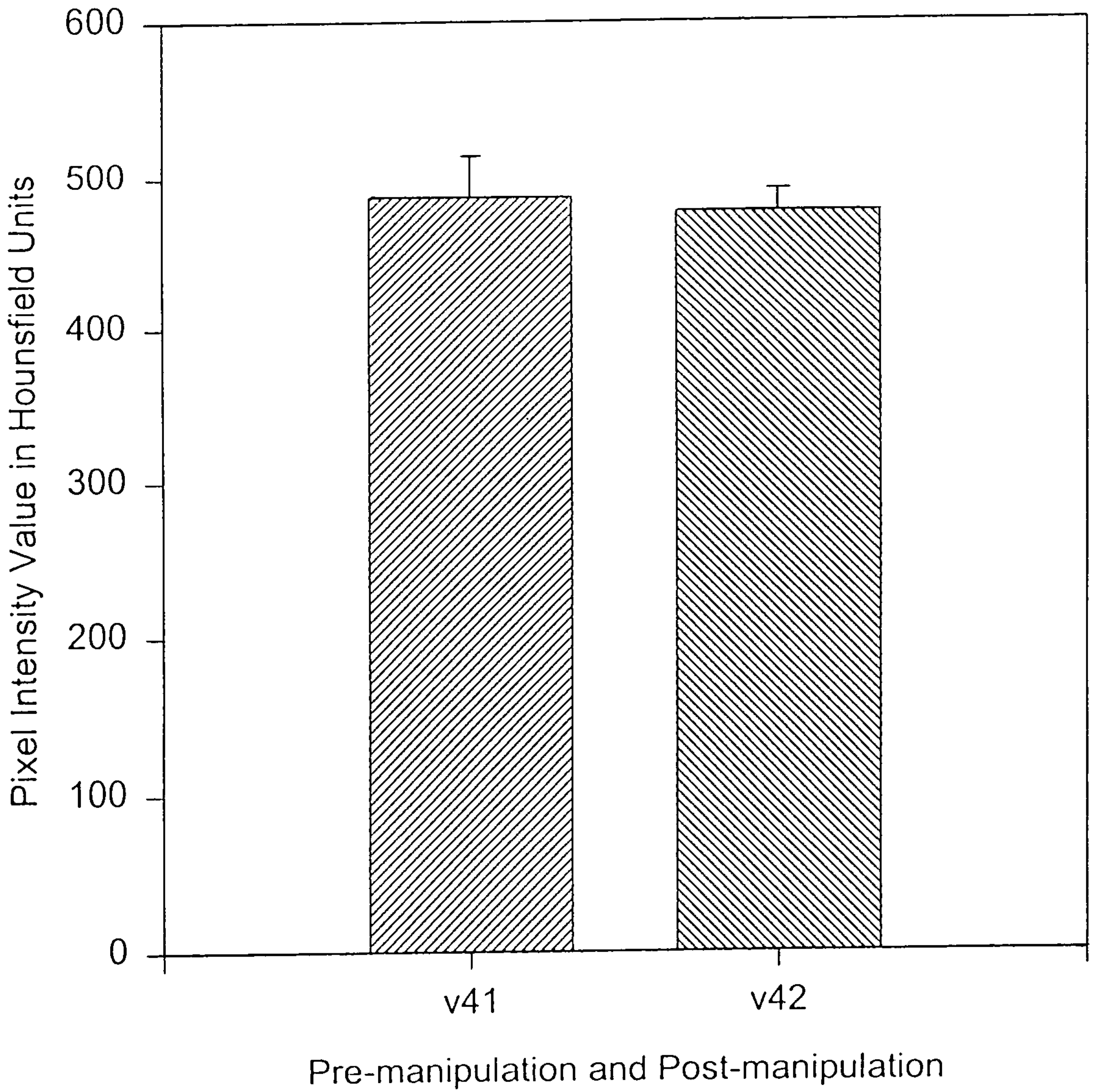
Graph 6: Average Total Defined Area of Joint Spaces at the C3-C4 Level



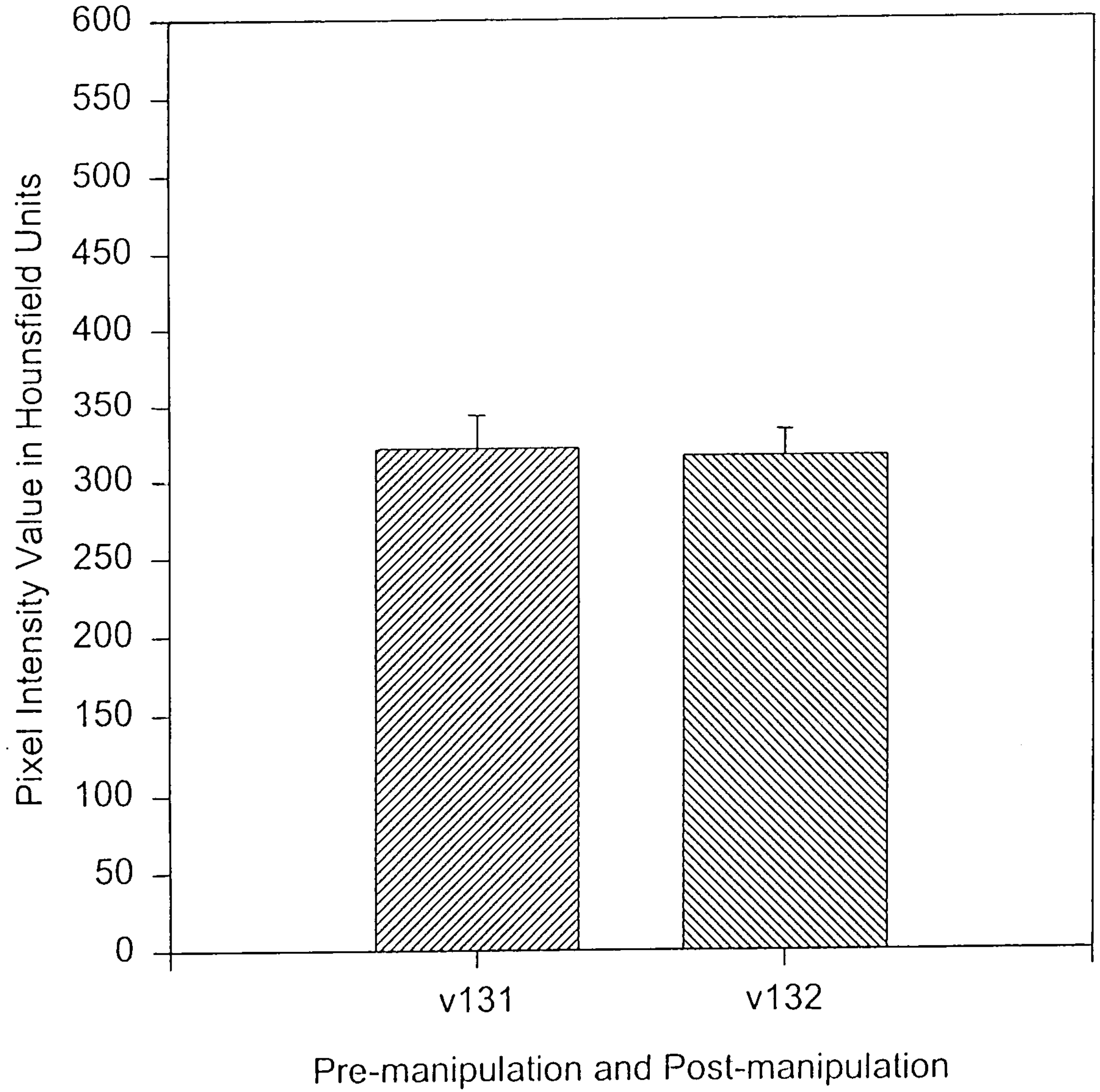
Graph 7: Average Pixel Intensity Value of all Joint Spaces + Traction



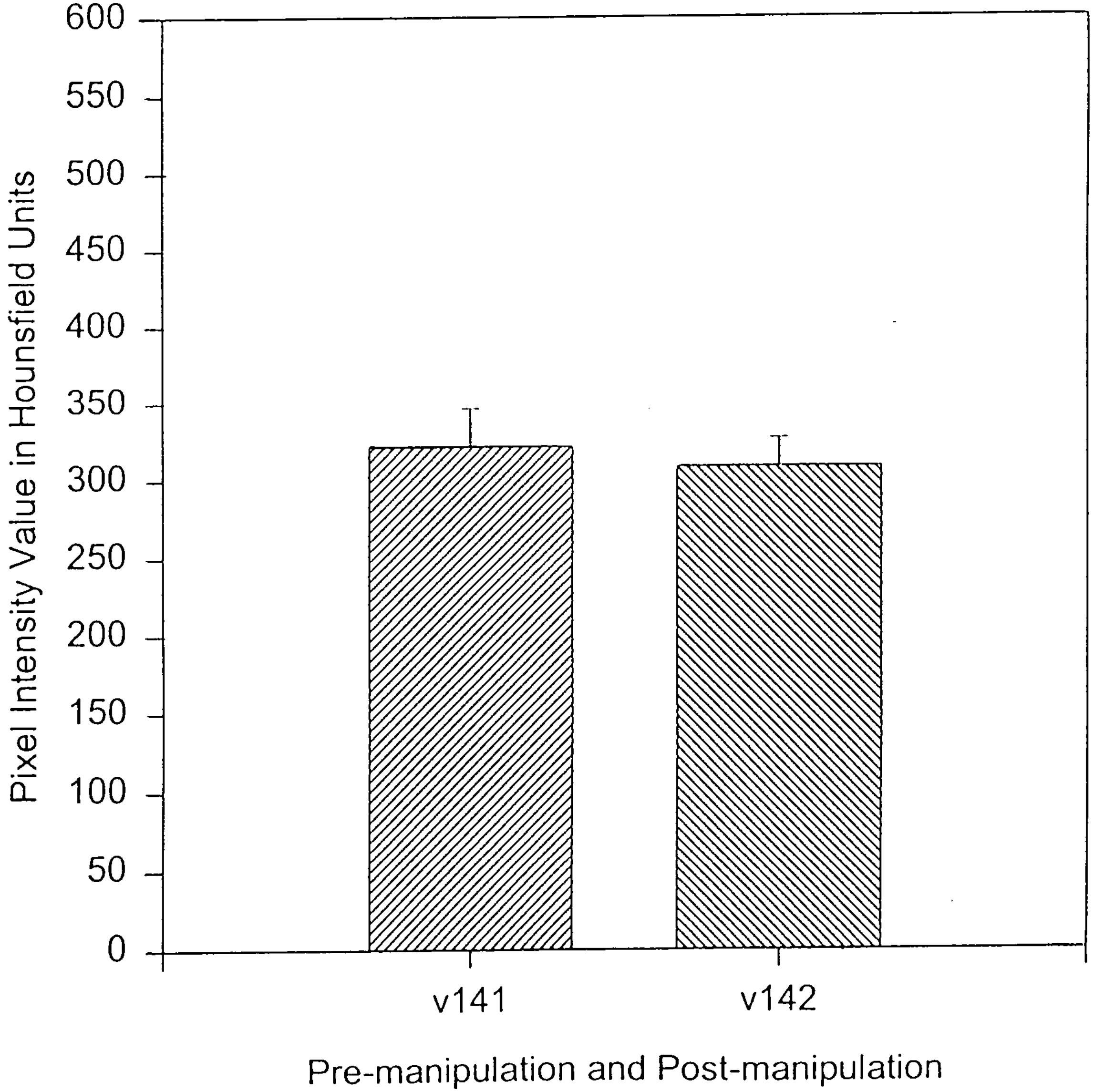
Graph 8: Average Pixel Intensity Value of the Joint Spaces at the C3-C4 Level



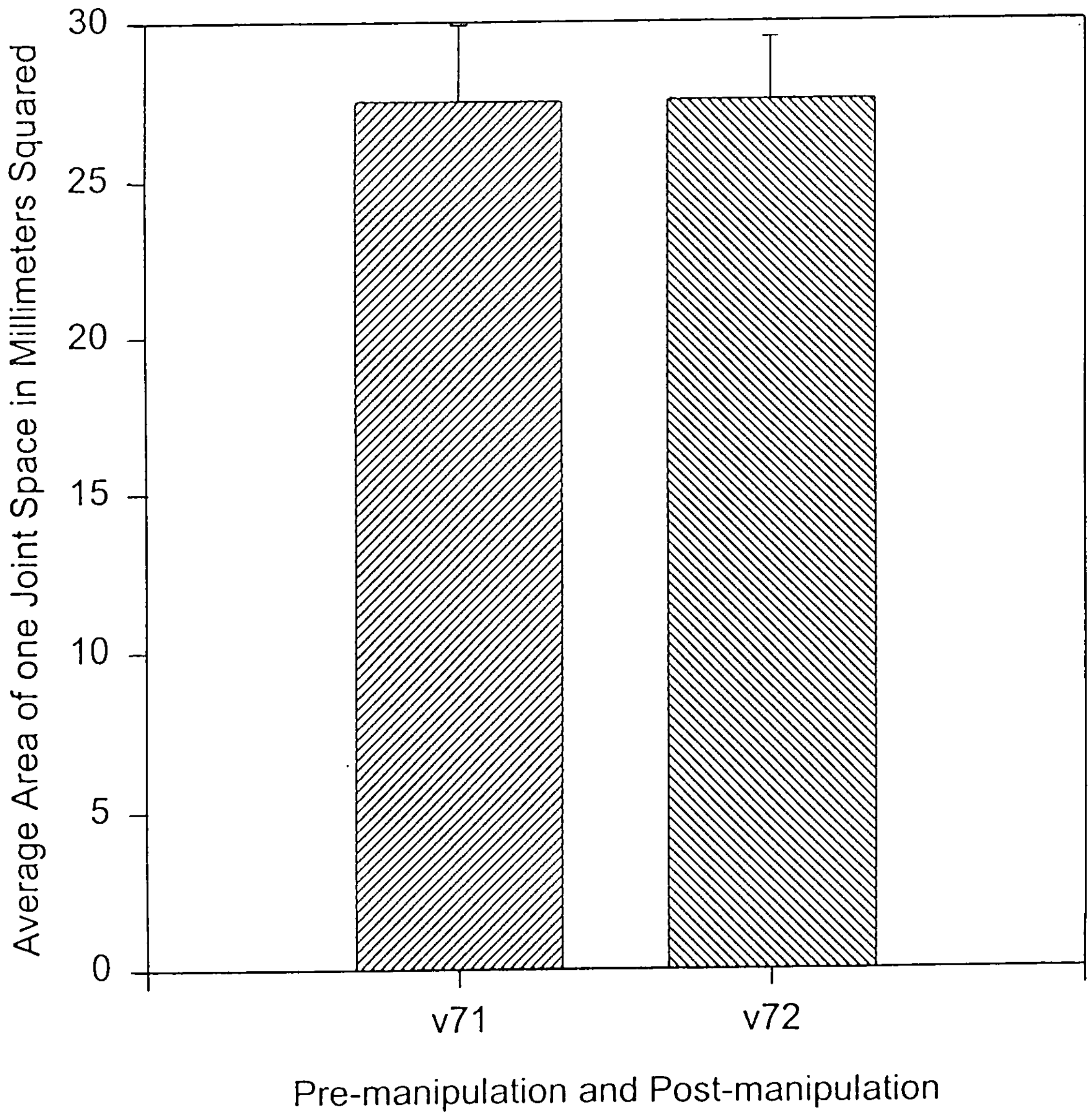
Graph 9: Minimum Pixel Intensity Value of all the Joint Spaces + Traction



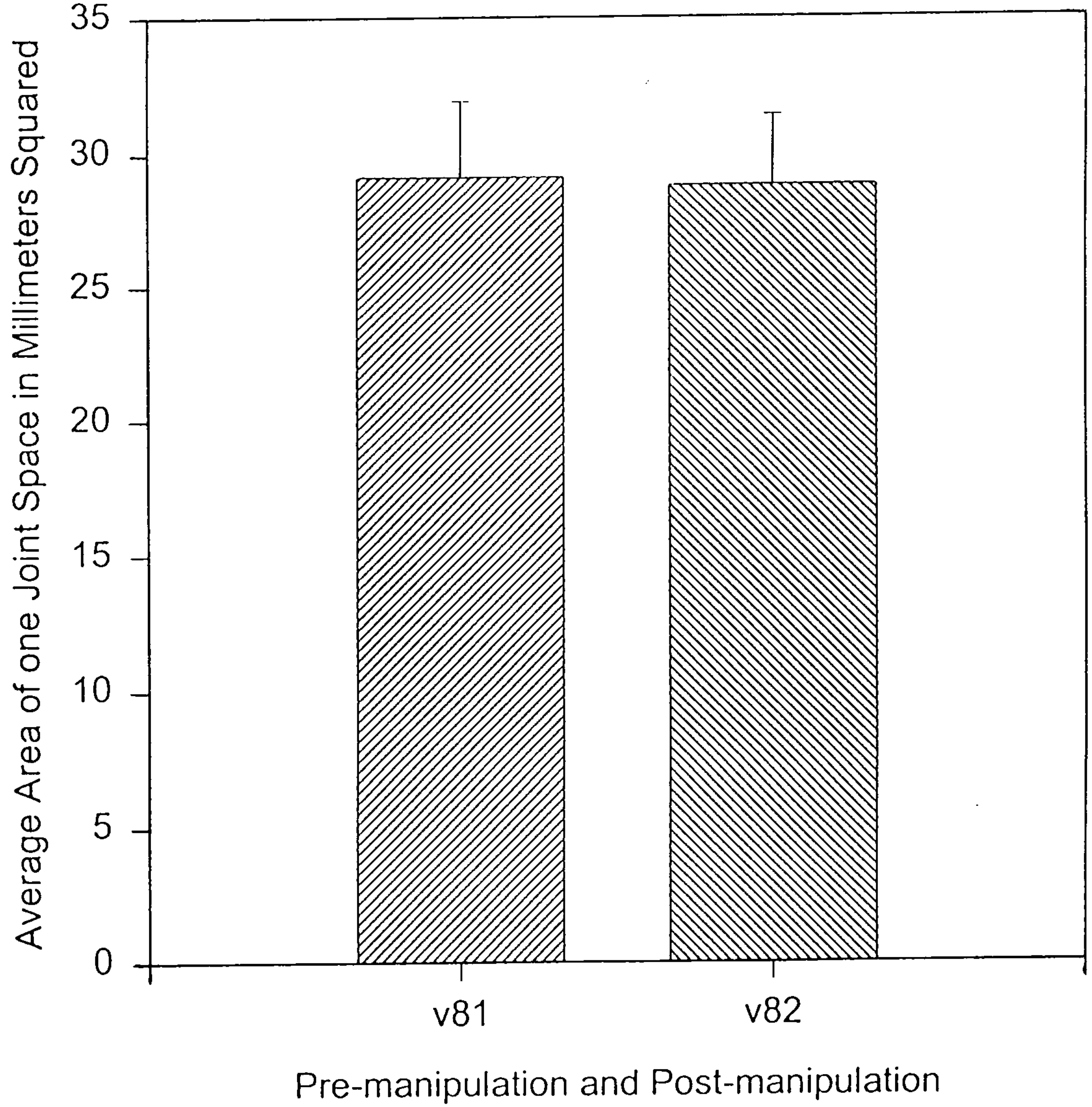
Graph 10: Minimum Pixel Intensity Value of the Joint Spaces at the C3-C4 Level + Traction



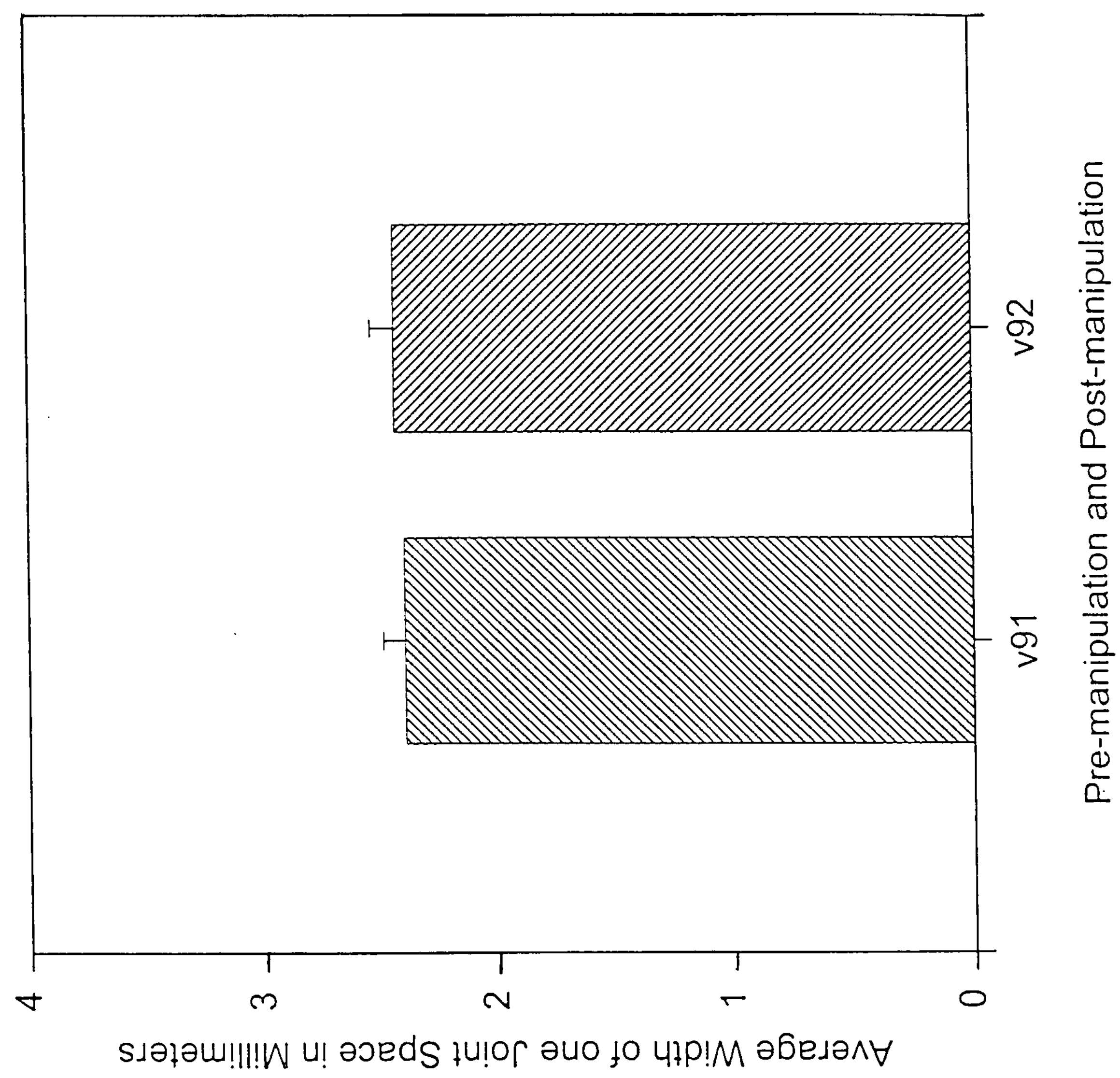
Graph 11: Average Total Defined Area of all Joint Spaces + Traction



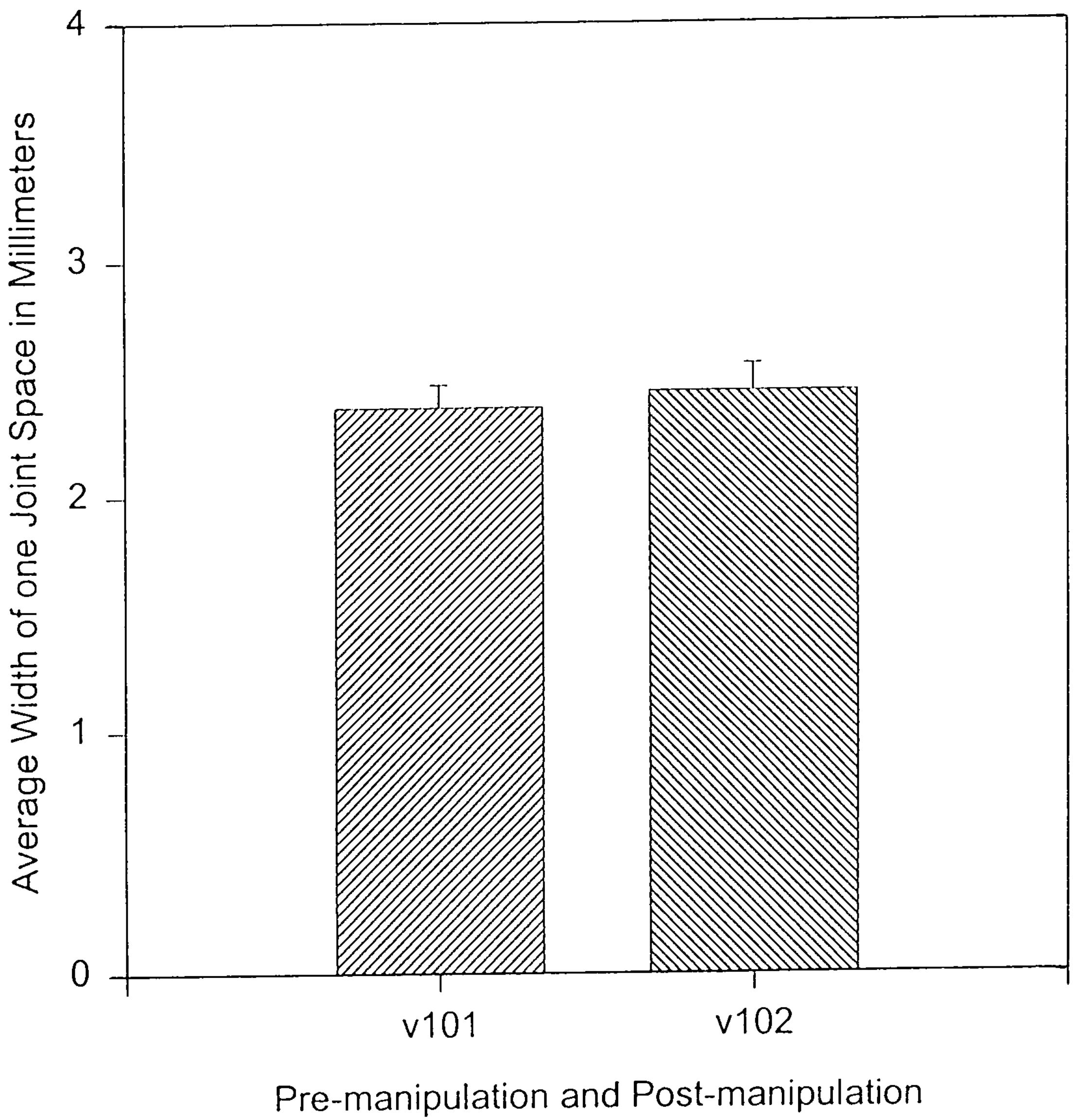
Graph 12: Average Total Defined Area of Joint Spaces at the C3-C4 Level + Traction



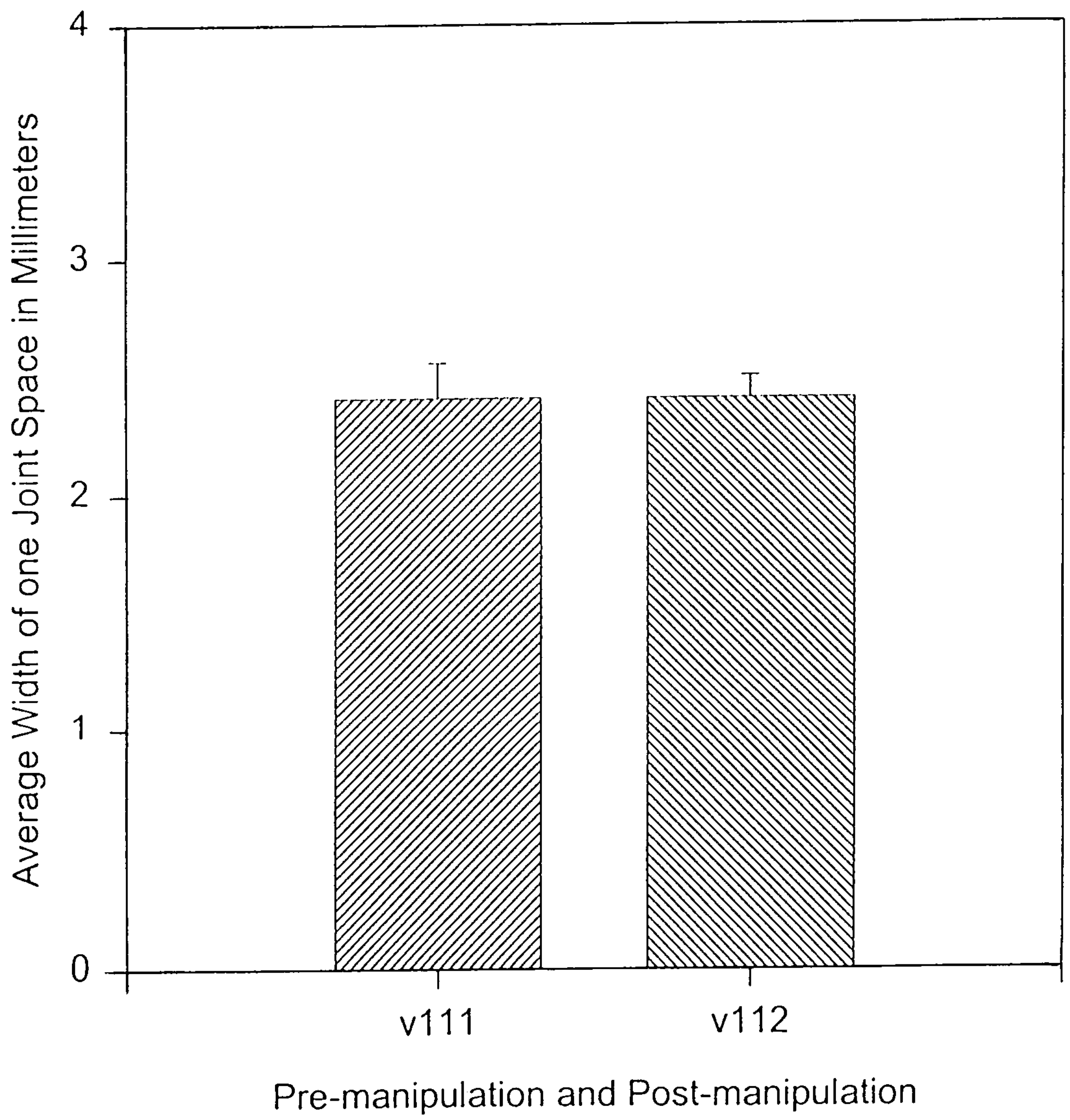
Graph 13: Average Width of all the Joint Spaces



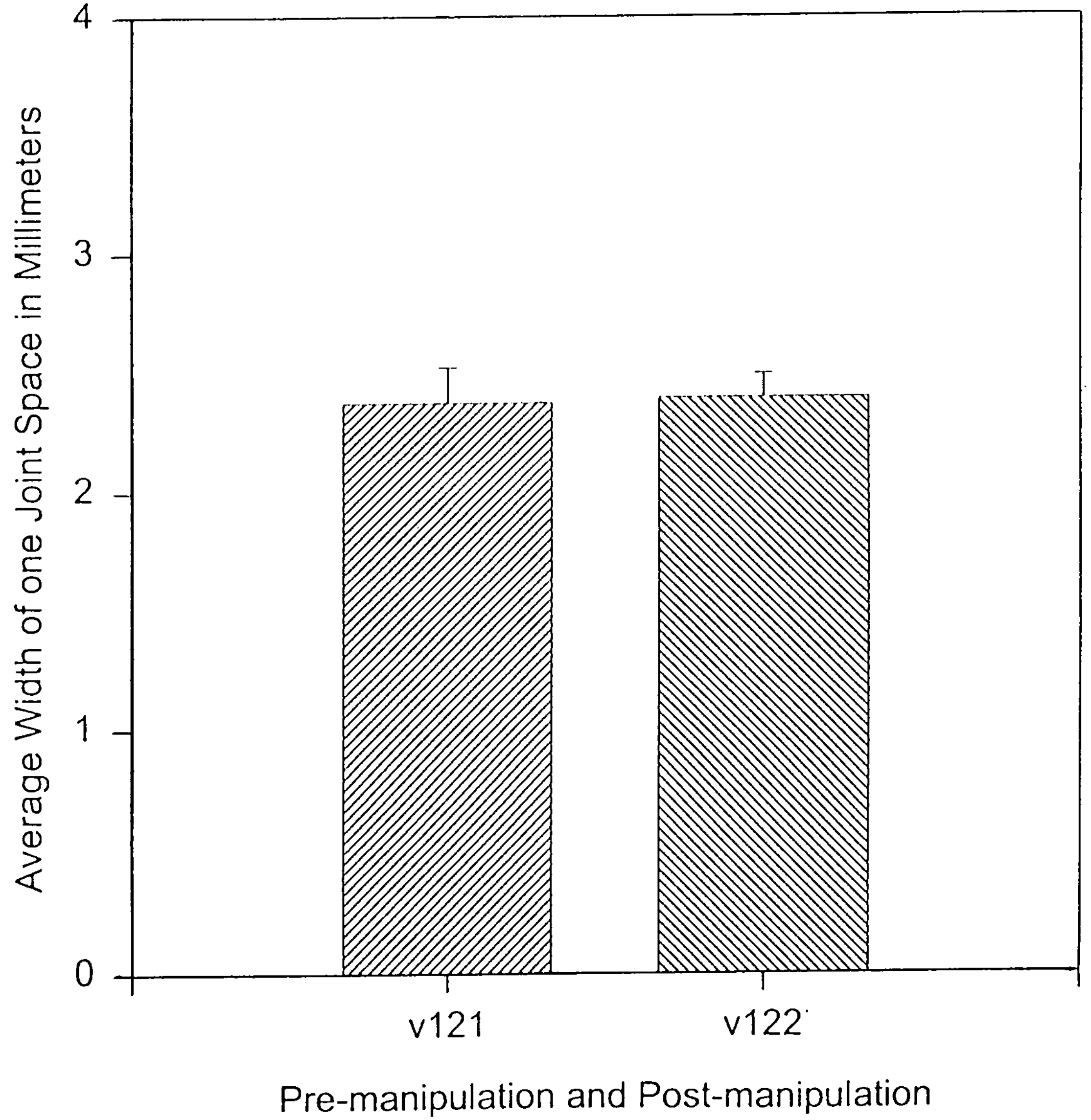
Graph 14: Average Width of the Joint Spaces at the C3-C4 Level



Graph 15: Average Width of all the Joint Spaces + Traction



Graph 16: Average Width of the Joint Spaces at the C3-C4 Level + Traction



CHAPTER 5

DISCUSSION

This chapter explores the results from this study. From a statistical point of view the results obtained from the combined experimental groups (i.e. Experiments 3+4+5+6) is the most valuable since it utilized 21 control (pre-manipulation) and 21 experimental (post-manipulation) subjects.

As was previously stated, no significant differences were noted at the 5% level of significance.

Thus immediately following a spinal manipulation with and without cervical traction:

- the distance between the subchondral margins, the area of the zygapophyseal joint spaces, and the density values of the zygapophyseal joint spaces did not significantly change.
- No visible radiolucent cavities/vacuum phenomena were demonstrated.

In addition to the above, it was noted that the density values of the zygapophyseal joint spaces following spinal manipulation were well above the density of air (-1000) and water (0).

The above is not consistent with the current understanding of cavitation, in particular the refractory period.

5.1 DISCUSSION OF EXPERIMENTS 3+4+5+6

The combined experimental group will be discussed first as it has the largest sample size. One must take into consideration that, for example, the pre-manipulation minimum pixel intensity value at the segmental level of manipulation whilst undergoing traction in Experiment 3 was added to the corresponding variables in Experiments 4, 5, and 6. This was then compared to the corresponding post-manipulation variable. However, the amount of traction applied to the subjects differed between the experimental groups. Thus, this discussion provides the general effects of the manipulation on the joints with and without traction. The discussion ignores exactly how much traction was applied (obviously it must be between 5 and 15kg due to the nature of the study) or whether the subjects cervical spines were in the neutral, forward flexed or lateral flexion plus rotation positions.

5.1.1 Average Pixel Intensity Value

The average pixel intensity value of one joint space (see pages 69-71), was 482.36 *before* and 491.08 *after* the manipulation (p= 0.325). Both figures represented an average tissue density higher than that of water but lower than dense bone. The fact that the figure increased following the manipulation is not consistent with our current understanding of joint cavitation. A possible reason for this observation could be that when the computer software was used to outline and analyze the joint spaces following the manipulation, more bony tissue at the periphery may have been included than in the pre-manipulation image. This means that when the computer calculates the average density of all the tissues in the joint space outlined, it would be increased slightly due to the presence of this dense tissue when compared to the corresponding data before the manipulation.

When comparing this data to that of the average pixel intensity at the C3-C4 level, 490.45 before and 484.07 after (p= 0.345), the trend is just the opposite. This observation is consistent with our current understanding of cavitation. Two possible reasons for this observation come to mind. The first one is the reverse of that outlined in the above paragraph. The second reason is that due to the presence of the hypothesized collapsed gaseous nucleus/micro-bubbles in the joint space following the manipulation, it would be decreased slightly due to the presence of this low density tissue when compared to the corresponding data before the manipulation. However, one might have expected a greater reduction if this had been the case. See Graphs 1 and 2.

5.1.2 Minimum Pixel Intensity Value

The minimum pixel intensity value of one joint space (see pages 69-71) was 318.45 *before* and 328.33 *after* the manipulation (p= 0.490). Both figures represented an minimum tissue density higher than that of water but lower than dense bone. The fact that the figure increased following the manipulation is not consistent with our current understanding of joint cavitation. It is not clear why this should be the case. Even if more bony tissue at the periphery was included when the computer software was used to outline and analyze the joint spaces following the manipulation, when the computer calculates the minimum density of the tissues in the joint space outlined it only searches the tissues with the lowest density and ignores the rest. Note that when calculating the average pixel intensity value, the computer includes all tissues included in the outline to determine the mean density.

When comparing this data to that of the minimum pixel intensity at the C3-C4 level (309.29 before and 318.60 after; p= 0.470), the trend is the same. This observation is also inconsistent with our current understanding of cavitation and it is not clear why this should be the case.

As this study focuses on the hypothesis of gas production following the manipulation within the joint space, and that gas is represented by a low value (negative Hounsfield unit), the minimum pixel intensity value is more important than the average pixel intensity value. This is because the minimum value represents the tissue of lowest density only, even if it is in the minority. However, the average value is also valuable as it informs one on the overall tissue density in the joint space. See Graphs 3 and 4.

5.1.3 Average of Total Defined Areas in mm^2

The average of the total defined area of one joint space (see pages 69-71) was 24.86 mm^2 *before* and 25.86 mm^2 *after* the manipulation (p= 0.391). This figure represents the average area of a single zygapophyseal joint space. The fact that the figure increased following the manipulation is consistent with our current understanding of joint cavitation. A possible reason for this observation is that due to a decrease in the co-aptative forces in the joint and/or a decrease in capsular tonicity following the manipulation, the joint surfaces separated slightly to increase the cross-sectional (axial view) area within the joint.

When comparing this data to that of the average total defined area at the C3-C4 level, 27.31 before and 26.52 after (p= 0.391), the trend is just the opposite. This observation is not consistent with our current understanding of cavitation and it is not clear why this should be the case. See Graphs 5 and 6.

5.1.4 Average Pixel Intensity Value + Traction

The average pixel intensity value of one joint space (see pages 69-71) was 491.78 *before* and 483.31 *after* the manipulation (p= 0.401). The fact that the figure decreased following the manipulation is consistent with our current understanding of joint cavitation.

Although unlikely (as the Hounsfield unit values are not in the negative range, and radiolucent cavities and an increase in joint space widths were not once demonstrated in any part of this study), this finding may be due to the presence of the hypothesized collapsed gaseous nucleus/micro-bubbles in the joint space following the manipulation. Thus the intra-articular density would be decreased slightly due to the presence of this low density tissue when compared to the corresponding data before the manipulation. The average pixel intensity should be lower after the manipulation with the application of a traction force (compared to without traction) because this distraction tends to separate the articular surfaces thus decreasing the intra-articular pressure. This decreased pressure is hypothesized to allow for the reformation of the collapsed gaseous nucleus/micro-bubbles into a radiolucent cavity with a much lower density. Although a visible radiolucent cavity was not seen, perhaps some of the collapsed nucleus/micro-bubbles reformed which accounted for the slight decrease in density.

When comparing this data to that of the average pixel intensity at the C3-C4 level undergoing traction, 486.75 before and 476.29 after ($p = 0.500$), the trend is the same. This observation is consistent with our current understanding of cavitation and the reasoning behind it is similar to the above explanation. See Graphs 7 and 8.

5.1.5 Minimum Pixel Intensity Value + Traction

The minimum pixel intensity value of one joint space (see pages 69-71) was 320.74 *before* and 315.29 *after* the manipulation ($p = 0.450$). Both figures represented an minimum tissue density higher than that of water but lower than dense bone. The fact that the figure decreased following the manipulation is consistent with our current understanding of joint cavitation. However, of some concern is that even during traction the lowest density recorded is nowhere near that of gaseous tissue. There is no clear reason why this should be the case.

When comparing this data to that of the minimum pixel intensity at the C3-C4 level undergoing traction, 321.03 before and 308.12 after ($p = 0.440$), the trend is the same. This observation is also consistent with our current understanding of cavitation. Similar to the above, the lowest density recorded at the segmental level of manipulation is also nowhere near that of gaseous tissue and it is not clear why this should be the case. See Graphs 9 and 10.

5.1.6 Average of Total Defined Areas in mm^2 + Traction

The average of the total defined area of one joint space (see pages 69-71) was 27.48 mm^2 *before* and 27.52 mm^2 *after* the manipulation ($p= 0.391$). This figure represents the average area of a single zygapophyseal joint space undergoing traction. The fact that the figure increased following the manipulation is consistent with our current understanding of joint cavitation since the traction should be more effective in separating the articular surfaces after the manipulation due to the decreased co-aptation. However, the increase is only marginal and not of a significant nature.

When comparing this data to that of the average total defined area at the C3-C4 level, 29.10 before and 28.79 after ($p= 0.352$), the trend is just the opposite. This observation is not consistent with our current understanding of cavitation and it is not clear why this should be the case. See Graphs 11 and 12.

5.1.7Joint Space Readings in Millimeters

The average distance between the subchondral margins of one joint space (see pages 69-71) was 2.40 mm. *before* and was 2.43 mm. *after* the manipulation ($p= 0.440$). The fact that the figure increased following the manipulation is consistent with our current understanding of joint cavitation.

When comparing this data to that of the joint space widths at the C3-C4 level, 2.38 before and 2.45 after (p= 0.290), the trend is the same. This observation is consistent with our current understanding of cavitation and the reasoning behind it is similar to the above explanation. The second decimal place should not imply that the researcher was measuring to the one-hundredth of a millimeter, these values are averages taken to the second decimal place. See Graphs 13 and 14.

5.1.8 Joint Space Readings in Millimeters + Traction

The average distance between the subchondral margins of one joint space (see pages 69-71) was 2.41 mm. *before* and 2.41 mm. *after* the manipulation (p= 0.334). The fact that the figure remained the same following the manipulation is not consistent with our current understanding of joint cavitation and it not clear why this should be the case

When comparing this data to that of the joint space widths at the C3-C4 level, 2.38mm. before and 2.40mm. after (p= 0.372), the width of the joint space increased. This observation is consistent with our current understanding of cavitation. See Graphs 15 and 16.

5.2 Discussion of Experiments 3, 4, 5, and 6

These individual experimental groups will be discussed second as they have smaller sample sizes. In this discussion, one may now focus on the more subtle particular characteristics of each experiment. Thus, this discussion provides the effects of the manipulation on the joints with and without traction and is concerned with exactly how much traction was applied and whether the subjects cervical spines were in the neutral, forward flexed or lateral flexion plus rotation positions.

5.2.1 Experiment 1

Particular to this experiment was that the subjects were not imaged in a tractioned position and that only fluoroscopy-assisted plain film imaging was utilized.

No radiolucent cavities were demonstrated on the post-manipulation radiographs. This finding is consistent with the cavitation model as the radiolucent cavity only becomes demonstrable when the joint is tractioned. The width of the joint spaces showed no significant change on the post-manipulation radiographs. This finding is not consistent with the findings of Unsworth et al. 1971, who reported a slight increase in the resting joint space width following manipulation in the metacarpophalangeal joints. However, this finding is consistent with those of Roston and Haines 1947 and Mierau, Cassidy et al. 1988, who reported that the joint space returns to its original width after the traction force is completely released. Also, if one examines (B) of Figure 3 no increase in joint space is demonstrated.

5.2.2 Experiment 2

Particular to this experiment was that the subjects were imaged in an 8kg. traction position in addition to a resting position before and after the manipulation and that only fluoroscopy-assisted plain film imaging was utilized.

No radiolucent cavities were demonstrated on the post-manipulation radiographs. This finding is not consistent with the cavitation model since a radiolucent cavity are demonstrable in the tractioned cavitated metacarpophalangeal joints utilizing plain film imaging. A possible reason for this finding is that because the imaging was performed on the cervical spine, which is much larger and more complex than the metacarpophalangeal joint, the sensitivity of plain film imaging is not sufficient to distinguish between gaseous and soft tissues in the cervical zygapophyseal joint which is approximately 2.4 millimeters wide.

However, a statistically significant decrease in the joint space density was noted after the manipulation with the subject in the traction position, which is consistent with the cavitation model. This density reading, however, is not in the range of gaseous tissue. The above density is an average density of the joint space indicating that, although unlikely, enough gas may have been present to decrease the overall joint density, but insufficient to be visually demonstrated in the joint space. The width of the joint spaces showed no significant change on the post-manipulation radiographs. A possible reason for the lack of a significant increase in joint space after the manipulation with the joint undergoing traction is that eight kilograms of traction is only sufficient to straighten out the cervical lordosis. Perhaps a greater amount of traction would then begin to separate the articulating surfaces.

5.2.3 Experiment 3

Particular to this experiment was that the subjects were imaged in 5kg. traction with the neck in the neutral position in addition to a neutral resting position before and after the manipulation and that computed tomographic imaging was utilized.

No radiolucent cavities (vacuum phenomena) were demonstrated in any of the post-manipulation images. It is not clear why this should be the case.

The density of the joint spaces showed no significant change following the manipulation. It is not clear why this should be the case.

The size of the joint spaces in terms of width and cross sectional area showed no significant change following the manipulation. This finding is not consistent with the cavitation model since an increase in the size of the joint space width and area should have occurred following the manipulation whilst undergoing traction.

5.2.4 Experiment 4

Particular to this experiment was that the subjects were imaged in an 8kg. traction position with the neck in forward flexion, in addition to a resting position with the neck in forward flexion before and after the manipulation and that computed tomographic imaging was utilized.

The results obtained were the same as in Experiment 3 with similar reasoning. The purpose of the neck being in forward flexion was an attempt to "open up" the zygapophyseal joints which lie posteriorly and thus facilitate the visualization of any radiolucent cavities. A possible reason for this failed attempt includes the fact that in forward flexion the inferior articular facets of the vertebrae above simply slide antero-superiorly over the superior facets of the vertebrae below without an increase in the distance between the articulating surfaces. A study by Wong et al. (see page 12) indicates that the zygapophyseal joint spaces decrease when the cervical spine is tractioned in the flexion position. Note that Wong et al. is comparing the resting joint space to the joint space following intermittent traction over 20 minutes. This study, however, is comparing the resting joint space before the manipulation to the resting joint space after manipulation, and the tractioned joint space before the manipulation to the tractioned joint space after the manipulation. This difference in methodology may account for the fact that in this experimental group no change in the joint space width was noted after the manipulation. This study did not attempt to compare the joint spaces before and after manipulation in extension and one therefore cannot be certain that extension would have resulted in a significant increase in the joint space widths following the manipulation.

5.2.5 Experiment 5

Particular to this experiment was that the subjects were imaged in an 8kg. traction position with the neck in lateral flexion and slight rotation, in addition to a resting position with the neck in lateral flexion and slight rotation before and after the manipulation and that computed tomographic imaging was utilized.

The results obtained were the same as in Experiment 3 and 4 with similar reasoning. The purpose of the neck being in lateral flexion with slight rotation (i.e. manipulation setup position) was an attempt to "open up" the zygapophyseal joints either under the contact point or on the opposite side at the same level, and thus facilitate the visualization of any radiolucent cavities. Reasoning for this failed attempt is similar to that discussed in Experiment 4.

5.2.6 Experiment 6

Particular to this experiment was that the subjects were imaged in 15kg. traction with the neck in the neutral position in addition to a neutral resting position before and after the manipulation and that computed tomographic imaging was utilized.

The results obtained were the same as in Experiment 3, 4, and 5. The purpose of utilizing 15kg. of traction was an attempt to apply a particularly forceful amount of traction which was still within subject tolerance levels to "open up" the zygapophyseal joints and thus facilitate the visualization of any radiolucent cavities. A possible reason for this failed attempt includes that perhaps even more traction force is required.

CHAPTER 6

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

6.1 Conclusions

Tests comparing the pre-manipulation data of Experiment 2 to the post-manipulation data of Experiment 2 indicated that :

- a decrease in the density readings of the joint spaces at the segmental level manipulation and adjacent levels + 8kg traction was present at the 5% level of significance and that
- a decrease in the density readings of the joint spaces at the segmental level manipulation + 8kg traction was present at the 5% level of significance.

However, the above significant decrease in joint space density following the manipulation was not sufficient to demonstrate a radiolucent cavity/ vacuum phenomenon in that joint, indicating that gas was not present in the zygapophyseal joint following the manipulation.

Also, the above significant differences were not associated with an increased joint space at the 5% level of significance, a phenomenon usually associated with the presence of radiolucent cavities in the joint space.

All other tests comparing the pre-manipulation data to the post-manipulation data on combined (i.e. Experiments 3+4+5+6) and individual experiment groups (i.e. Experiments

1 to 6) indicated that no significant differences were present at the 5% level of significance.

Thus immediately following a spinal manipulation :

- the distance between the subchondral margins of the zygapophyseal joints did not significantly change
- the area of the zygapophyseal joint spaces did not significantly change
- the density values of the zygapophyseal joint spaces did not significantly change and
- no visible radiolucent cavities/vacuum phenomena were demonstrated

In addition to the above, it was noted that the density values of the zygapophyseal joint spaces following spinal manipulation were well above the density of air (-1000) and water (0).

The above is not consistent with the current understanding of cavitation, in particular the refractory period.

As far as the researcher is aware, a study of this kind has never been attempted before and therefore it has shown that a research of this kind is possible.

6.2 Limitations

The most important limitation of this study was the small sample size, particularly in the individual experimental groups. This study did not include views with the subject's neck in an extension position. Wilcoxon signed rank tests could only be performed between Experiments 5 and 6 because these were the only groups containing equal sample sizes.

6.3 Recommendations

Future studies involving larger traction forces (i.e. greater than 15kg.) before and after the manipulation, different positioning of the subject's neck (e.g. extension), and the use of Magnetic Resonance Imaging are suggested which may produce new knowledge in this field of research.

REFERENCES

Beffa R. 1996. Investigation into the Origin of Cavitation Sounds. Unpublished Dissertation in the Library at Technikon Natal, Durban, South Africa.

Brodeur R. 1995. The audible release associated with joint manipulation. Journal of Manipulative and Physiologic Therapeutics, 18:155-163.

Chen Y.L., Israelachvili. 1991. New mechanism of cavitation damage. Science, 252:1157-1160

Curry T.S., Dowdey J.E., Murry R.C. 1990. Christensen's Physics of Diagnostic Radiology . 4th edition. Lea and Febiger. Philadelphia, London. 1-522 p. ISBN 0-8121-1310-1.

Grieve G. 1982. Neck Traction. Physiotherapy, 68:260-265.

Herzog W., Conway P.J., Kawchuck G.N., Zhang Y., Hasler E.M. 1993. Forces exerted during spinal manipulative therapy. Spine, 18:1206-1212.

Herzog W. 1991. Biomechanical studies of spinal manipulative therapy. Journal of the Canadian Chiropractic Association, 35:156-164.

Herzog W., Zhang Y.T., Conway P.J.W., Kawchuck G. 1993. Cavitation sounds during spinal manipulative treatments. Journal of Manipulative and Physiologic Therapeutics, 16:523-526.

Herzog W., 1994. The biomechanics of spinal manipulative treatments. Journal of the Canadian Chiropractic Association, 38:216-222.

Kawchuck G.N., Herzog W., Hasler E.M. 1992. Forces generated during spinal manipulative therapy of the cervical spine : a pilot study. Journal of Manipulative and Physiologic Therapeutics, 15:275-278.

Meal G.M., Scott R.A. 1986. Analysis of the joint crack by simultaneous recording of sound and tension. Journal of Manipulative and Physiologic Therapeutics, 9:189-195.

Mierau D., Cassidy J.D., Bowen V., Dupuis P., Noftall F. 1988. Manipulation and mobilization of the third metacarpophalangeal joint. Manual Medicine, 3:135-140.

Reggars J.W., Pollard H.P. 1995. Analysis of zygapophyseal joint cracking during chiropractic manipulation. Journal of Manipulative and Physiologic Therapeutics, 18:65-71.

Resnick D., Niwayama G.1988. Diagnosis of Bone and Joint Disorders. 2nd Edition. W.B. Saunders Company. Philadelphia London Montreal Sydney Tokyo. 274-275;1491-1492 p. ISBN 0-7216-1481-7.

Roston J.B., Haines R.W. 1947. Cracking in the metacarpophalangeal joint. Journal of Anatomy, 18:165-173.

Sandoz R., Neuchatel. 1969. The significance of the manipulative crack and other articular noises. Annals of the Swiss Chiropractors' Association, 4:47-68.

Sandoz R. 1976. Some physical mechanisms and effects of spinal adjustments. Annals of the Swiss Chiropractors' Association, 6:91-141.

Semlak K., Ferguson A.B. 1963. Joint stability maintained by atmospheric pressure. Clinical Orthopaedics and Related Research, 68:294-300.

Triano J.J., 1992. Studies on the biomechanical effect of a spinal adjustment. Journal of Manipulative and Physiologic Therapeutics, 15:71-75.

Unsworth A., Dowson D., Wright V. 1971. Cracking joints : a bioengineering study of cavitation in the metacarpophalangeal joint. Annals of Rheumatic Disease, 30:348-358.

Watson P., Kernohan W.G., Mollan R.A.B. 1989. A study of the cracking sounds from the metacarpophalangeal joint. Journal of Engineering in Medicine, 203:109-119.

Watson P., Mollan R.A.B. 1990. Cineradiography of a cracking joint. British Journal of Radiology, 63:145-147.

Watson P., Kernohan W.G., Mollan R.A.B. 1989. The effects of ultrasonically induced cavitation on articular cartilage. Clinical Orthopaedics and Related Research, 245:288-296.

Wong A.M.K., Leong C.P., Chen C. 1992. The traction angle and cervical intervertebral separation. Spine, 17:136-138.

APPENDICES

A

TECHNIKON NATAL CHIROPRACTIC DAY CLINIC

CASE HISTORY

Patient: ______________________________ Date #: ____________

File #: ____________

X-ray #: ____________

Age: __________ Sex: ______ Occupation: ____________

Intern: __________________________ Signature: ____________

FOR CLINICIAN'S USE ONLY

Initial visit clinician: Signature:

Case History:

Examination:

Previous:	TN Other	Current:	TN Other

X-ray Studies:

Previous:	TN Other	Current:	TN Other

Clinical path. lab.:

Previous:	TN Other	Current:	TN Other

Case status:

PTT: Conditional: Signed off: Final sign out:

Recommendations:

Intern's case history

1. Source of history:

2. Chief complaint: (patient's own words)

3. Present illness:

   Location

   Onset

   Duration

   Frequency

   Pain (character)

   Progression

   Aggravating factors

   Relieving factors

   Associated S & S

   Previous occurrences

   Past treatment and outcome

4. Other complaints:

5. Past history:

General health status

Childhood illnesses

Adult illnesses

Psychiatric illnesses

Accidents/injuries

Surgery

Hospitalizations

6. Current health status and life-style:

- Allergies
- Immunizations
- Screening tests
- Environmental hazards (home, school, work)
- Safety measures (seat belts, condoms)
- Exercise and leisure
- Sleep patterns
- Diet
- Current medication
- Tobacco
- Alcohol
- Social drugs

7. Family history:

Immediate family:

- Age
- Health
- Cause of death
- DM
- Heart disease
- TB
- HBP
- Stroke
- Kidney disease
- CA
- Arthritis
- Anaemia
- Headaches
- Thyroid disease
- Epilepsy
- Mental illness
- Alcoholism
- Drug addiction
- Other

8. Psychosocial history:

Home situation

Daily life

Important experiences

Religious beliefs

9. Review of systems:

General

Skin

Head

Eyes

Ears

Nose/sinuses

Mouth/throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematologic

Endocrine

Psychiatric.

B

TECHNIKON NATAL

TECHNIKON NATAL CHIROPRACTIC DAY CLINIC.

REGIONAL EXAMINATION -- CERVICAL SPINE.

PATIENT:_______________ ______________________________

FILE # :____________________ DATE:____________________

INTERN/RESIDENT:______________________________________

SUPERVISING CLINICIAN :_______________________________

OBSERVATION :

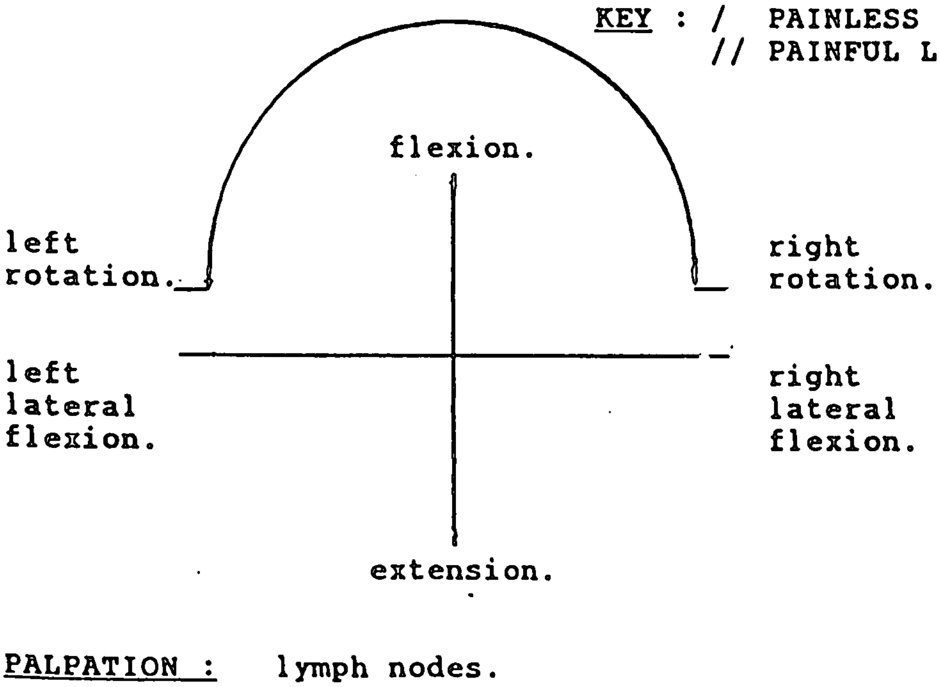
Posture
Swellings
Scars
Discoloration
Hair Line
Bony and soft tissue contours

Shoulder position:
Left =
Right =
Muscle spasm
Facial expression

RANGE OF MOTION:

Flexion = 45 degrees.
Extension = 70 degrees.
L/R Rotation = 70 degrees.
L/R Lateral flexion = 45 degrees.

KEY : / PAINLESS LIMITATION.
// PAINFUL LIMITATION.



PALPATION : lymph nodes.
trachea.
thyroid gland.

ORTHOPAEDIC EXAMINATION :

Tenderness
Active MF Trigger Points :
- SCM.
- Trapezius.
- Scaleni.
- Levator Scapulae.
- Posterior Cervical musculature.

Doorbell Sign	Cervical Compression
Kemp's Test	Lateral Compression
Cervical Distraction	Adson's Test
Halstead's Test	Costoclavicular Test
Hyperabduction Test (Wright's)	Eden's (traction) Test
Shoulder abduction Test	Shoulder depression Test.
Dizziness rotation Test	Lhermitte's Sign
Brachial Plexus Tension	O'Donoghue Manoeuvre

Remarks :____

____

____

____

NEUROLOGICAL EXAMINATION :

DERMATOMES: Left	Right.	MYOTOMES: Left	Right.	REFLEXES: Left	Right.
C2		C1		C5	
C3		C2		C6	
C4		C3		C7	
C5		C4			
C6		C5			
C7		C6			
C8		C7			
T1		C8			
		T1			

VASCULAR :

	LEFT.	RIGHT.
BLOOD PRESSURE.		
CAROTIDS.		
SUBCLAVIAN ARTERIES.		
WALLENBERG'S TEST.		

COMMENTS:

MOTION PALPATION :

Jt.play		Left						Right					Jt.play	
P/A	Lat	Fle	Ext	LF	AR	PR		Fle	Ext	LF	AR	PR	P/A	Lat
							C0							
							C1							
							C2							
							C3							
							C4							
							C5							
							C6							
							C7							
							T1							
							T2							
							T3							
							T4							