The effect of a scuba diving cylinder on static lumbar spine posture.

By

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A dissertation submitted to the Faculty of Health in partial compliance with the requirements for a Master's Degree in Technology: Chiropractic at Technikon Natal.

I, Christopher Anthony Ananiadis do hereby declare that this dissertation represents my own work in both conception and execution.

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Christopher Anthony Ananiadis   Date

Approved for final submission

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Dr Robert Mathews, M. Tech. Chiropractic   Date

DEDICATION

I dedicate this work to:

My always-supportive family who have been very patient and loving throughout my life and my studies.

(Mom, Dad, Denis)

To all my friends that have been with me during the course of my studies and seeing me through the easy and hard times.

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ABSTRACT

The purpose of this study was to evaluate the effect of wearing a scuba diving cylinder on static lumbar spine posture, in terms of clinical objective findings, namely radiographic changes in the lumbar lordosis, lumbosacral angle, lumbosacral disc angle, and the lumbar gravity line, during upright standing on land.

The study was a prospective, purposive trial using convenience sampling and incorporated 30 male volunteers between the ages of 18 and 45 years from the general population. The volunteers were subjected to 2 x-rays, one x-ray without the scuba diving cylinder (non-weight bearing) and another with the scuba diving cylinder (weight bearing). The volunteers stood in an erect neutral position conforming to normal erect standing posture (Magee, 1992: 596). This was repeated for both x-rays.

Four measurements were taken from each x-ray: lumbar lordosis, lumbosacral angle, lumbosacral disc angle, and lumbar gravity line. The measurements from the x-rays without the scuba diving cylinder were compared with changes to those with the scuba diving cylinder. These measurements were also then compared to that of literature based normative ranges (Yochum and Rowe, 1996: 159-163).

Statistical analysis made use of a 5% level of significance. Paired t-tests were used to analyse data between the non-weight bearing and weight bearing results. One-sample t-tests were used to analyse the measurements from each x-ray to that of the already established norms.

In terms of the findings between the measurements taken without the scuba cylinder and with the scuba cylinder: Statistical analysis of the lumbar lordosis showed there was no change. There was only a 0.4 degree difference radiographically between the non-weight bearing measurement to that of the weight bearing measurement.

On statistical analysis, the lumbosacral angle showed there was a statistically significant difference. There was a 2.57 degree increase of the lumbosacral angle as a result of the scuba diving cylinder but this was of no real radiographic significance, as this value was still within normative ranges.
On statistical analysis of the lumbosacral disc angle, there was a statistically significant difference. There was a 2.36 degree decrease in the lumbosacral disc angle as a result of the scuba diving cylinder and this may be linked to the flattening of the spine. The lumbosacral disc angle with the scuba diving cylinder was still, however, within normative ranges and of no real radiological significance.

On statistical analysis, the lumbar gravity line showed no statistically significant change, but there was a radiographically significant change of 8.7mm in an anterior direction due to the scuba diving cylinder. This may be linked to the forward tilting of the body to compensate for the change in the body's centre of gravity.

The results without the scuba diving cylinder and then with the scuba diving cylinder, in comparison with that of literature based normative values, showed that there was a statistically significant difference in lumbar lordosis. The study group showed an increased lordosis without the scuba diving cylinder but this measurement was still within normal radiographic parameters. With the scuba diving cylinder on, the lumbar lordosis was still within normative radiographic parameters.

Statistical analysis of the lumbosacral angle showed that there was a statistically significant difference with the scuba diving cylinder on. The change observed was still within normal radiographic parameters. Statistical analysis of the lumbosacral disc angle showed that there was a statistically significant difference in both the measurements. The measurement without the scuba diving cylinder was greater than the norm. The 7.6 degree difference has radiographic significance due to the possibility of facet impaction. The measurement with the scuba diving cylinder was 2.3 degrees less than the measurement without the scuba diving cylinder. This may be linked to flattening of the spine and an anterior shift in body's centre of gravity during weight bearing.

Statistical analysis of the lumbar gravity line showed there was a statistically significant difference in both the measurements. The measurement without the scuba diving cylinder was posterior to the anterior tip of the sacrum. Without spinal loading this measurement was of no radiological significance. The measurement, with the scuba diving cylinder on showed the lumbar gravity line to be 2.89mm anterior to the tip of the sacrum, which was of no radiological significance and still within normative ranges.

It was concluded that even though there were statistically significant differences in certain measurements when wearing the scuba diving cylinder, these changes were still within the established normative range. It would therefore appear that wearing the scuba diving cylinder does not change the lumbar posture radiographically enough, to be considered significant in terms of predisposition to injury.

Static posture is only a starting point of injury prediction. Further consideration of factors such as activities engaged, duration of wearing the cylinder and pre-existing spinal lesions warrant further investigation.

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ABBREVIATIONS USED IN CHAPTER FOUR

LL 1- Lumbar lordosis non-weight bearing

LL 2- Lumbar lordosis weight bearing

LSA 1- Lumbosacral angle non-weight bearing

LSA 2- Lumbosacral angle weight bearing

LSDA 1- Lumbosacral disc angle non-weight bearing

LSDA 2- Lumbosacral disc angle weight bearing

LGL 1- Lumbar gravity line non-weight bearing

LGL 2- Lumbar gravity line weight bearing

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CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

When investigating the epidemiology of low back pain one cannot help notice that it has become major health problem worldwide (Walker, 1997). A review by Walker of associated literature concerning the epidemilogy of low back pain, revealed that low back pain has a point prevalence of between 11% and 33%, a 1-year prevalence between 16% and 64%, and lifetime prevalence between 31% and 80%. Annual incidences range between 1% and 8% (Walker, 1997). An epidemiological investigation by Van der Meulen (1997) indicated that a lifetime incidence of low back pain in South Africa was 57.6% and the lifetime prevalence was 53.1%. This suggests that low back pain is also a common occurrence in South Africa.

Scuba diving has become a popular sport in the world today. The scuba diving community is composed of many different types of people, some pursuing it as a profession, and others for recreational purposes (Shannon, 2000). As a committee member of the Durban Under Sea Club the researcher has noticed a high incidence of low back pain as a result of wearing the scuba diving cylinder before water entry, and has questioned the effect of the weight of the scuba diving cylinder in the cause of injury.

In this study the effect of wearing a scuba diving cylinder on the static lateral posture of the lumbar spine was examined. With the knowledge of already defined radiological parameters in the lumbar spine for etiological and differential diagnostic indicators for low back pain (Yochum and Rowe, 1996: 159), one can look at the effect the scuba diving cylinder has on the lumbar spine, in terms of radiological data gathered in a research setting. This was done by using accepted radiographic measurements, namely: lumbar lordosis, lumbosacral angle, lumbosacral disc angle, and lumbar gravity line (Yochum and Rowe, 1996: 159-163). The measurements taken from the lateral lumbar spine x-rays were used to compare the changes caused by wearing the scuba diving cylinder with accepted radiographic norms for lateral lumbar posture.

The mechanism of injury to the lower back normally involves two different mechanisms. These are: rotational and compressive forces (Kirkaldy-Willis and Burton, 1992: 419). The scuba diving cylinder induces a superior to inferior load thus applying compression to the lumbar spine. At any one level the intervertebral joint is made up of three parts, formed by the two posterior facet joints and the intervertebral disc. The changes caused in the angles measured in this study can be linked to injury to all three parts. Compressive forces put more pressure on the intervertebral disc and are more likely to cause injury to the intervertebral disc, while rotational forces apply pressure to the posterior facet joints and are more likely to cause injury to the posterior facet joints (Kirkaldy-Willis and Burton, 1992: 419).

Axial torque of the lumbar spine can lead to damage and irritation in the anterior and posterior elements of the lumbar spine, but with torsional loading about the vertical axis, most of the loading will be borne by the posterior elements (White and Panjabi, 1990:384). While wearing the scuba diving cylinder the author postulates that these two mechanisms of injury may be occurring.

On observation of the scuba diver’s posture before water entry, whilst wearing the scuba diving cylinder, it is very likely that both compressive and rotational forces are created. The author speculates that exposure of the lumbar spine to forces created by the scuba cylinder may very well increase the risk of mechanical low back pain.

1.2 AIM

The purpose of this study was to evaluate the effect, the wearing of a scuba diving cylinder has, on static lumbar spine posture, in terms of the radiographic changes in the lumbar lordosis, lumbosacral angle, lumbosacral disc angle, and the lumbar gravity line. In order to see if the change, in the described angles, may be a factor in the cause of mechanical low back pain in scuba divers.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Research has shown that changes in spinal postural alignment, mainly the lumbar lordosis, lumbosacral angle, lumbosacral disc angle, and the lumbar gravity line, can be related to the aetiology of low back injury (Yochum and Rowe, 1996: 159-163).

Many studies have been conducted on the role of normal spinal posture and it has been found that there are no differences in the sagital profile of the lumbar spine across geographically and ethnically different populations (Harrison, 2000: 10). This is important as scuba diving is a sport that includes geographically and ethnically different people.

The effects of different loads on the lumbar spine have been studied and the possible outcomes discussed (Adams and Hutton, 1980: 1464), from the research conducted by Adams and Hutton it was concluded that loading in the lumbar spine during erect posture could produce backache and degenerative changes.

Current literature has helped to try estimate (predict) or understand the nature of spinal loading, and resultant injury, and with this knowledge one can try guide a strategy of intervention to reduce injury statistics (Goel and Weinstien, 1990: 66).

2.1.1 EPIDEMIOLOGY

When investigating the epidemilogy of low back pain one cannot help notice that it is a major health problem worldwide (Walker, 1997: 95). A review by Walker of associated literature revealed that low back pain has a point prevalence of between 11% and 33%, a 1-year prevalence between 16% and 64%, and lifetime prevalence between 31% and 80%. Annual incidences range between 1% and 8% (Walker, 1997: 95).

The costs associated with low back pain are astronomical with estimates approaching US$ 100 billion per annum in the US. There is also a global trend of vast amounts of revenue spent on low back pain each year (Walker, 1997: 96).

An epidemiological investigation by Van der Meulen (1997) indicated that a lifetime incidence of low back pain in South Africa was 57.6% and the lifetime prevalence was 53.1%. This suggests that low back pain is also a common occurrence in South Africa.

2.1.2 SCUBADIVING EQUIPMENT

A commonly used scuba diving cylinder by South African males is the 12 litre cylinder and weighs approximately 12 - 18 kilograms when filled with air, depending on the model and manufacture type (Shannon, 2000). Each scuba tank has specific markings on it describing its manufacture type, material make up, weight, and maximum pressure to which it may be filled (Mountain, 1996: 13). The scuba diving tank is worn on the back between the shoulder blades by means of a tank holder and a harness (Appendix l).

2.1.3 DENSITY AND HYDROSTATICS

The physical laws of density and hydrostatics govern the postural effect of the scuba diving cylinder in water as opposed to out of water. The principle of hydrostatics states that, "When a body is wholly or partially immersed in a liquid, it is pushed upwards by a force equal to the weight of the liquid displaced", this is also known as the Archimedes principle (Clough-Smith, 1978: 5). This causes the scuba tank to be lighter in the water than on land, thus changing the effect the weight of the scuba tank has on lumbar spine posture.

Therefore the lumbar spine is exposed to greater risk of mechanical injury while wearing the scuba tank on land compared to water.

2.2 RADIOLOGICAL PARAMETERS

There is evidence that radiologically measured parameters in the lumbar spine have value as both etiological and differential diagnostic indicators for low back pain (Yochum and Rowe, 1996: 159-171), namely the lumbar lordosis, lumbosacral angle, lumbosacral disc angle, and lumbar gravity line with regards to this study.

2.2.1 LUMBAR LORDOSIS

The lumbar lordosis is the anteroposterior curvature of the lumbar spine (Moore, 1992: 327). The average lumbar lordosis normally measures from 50 to 60 degrees (Yochum and Rowe, 1996: 159). An average of 55 degrees was taken as the normal in this study, because statistical analysis can only compute single figures and not a broad outline. Other studies on lumbar lordosis have both defined that the normal lumbar lordosis range is between 55 and 65 degrees (Harrison *et al.*, 1998), (Cailliet *et al.*, 1997).

2.2.1.1 STUDIES ON LUMBAR LORDOSIS

Harrison *et al.* 1998 studied 4 groups of people: (1) 50 normal subjects from a pre-employment physical screening, (2) 50 patients with acute lower back pain (first occurrence less than 6 weeks duration), (3) 50 patients with chronic low back pain (pain of greater than 6 weeks duration or a history of recurrent disabling low back pain), (4) 24 patients with low back pain and radiologically defined degenerative disorders or pathosis. It was found that statistical analysis was significantly different across the groups for the measurements taken. The chronic low back pain and lumbar pathosis group had a decreased lordosis, whereas the acute low back pain group had an increased lordosis to that of the normal subjects. Changes in lordosis from that of literature based norms may be used as indicators of low back pain, thus linking changes in lordosis with low back pain.

Banks (1983) found that an increased lumbar lordosis is of significant importance in its relation to low back pain. When wearing the scuba diving cylinder the lumbar lordosis may be increased and this could be linked to low back pain.

A study using 40 cadervic specimens of the lumbar spine showed that, in erect standing, the apophseal joints took 10% of the intervertebral compressive forces (Adams and Hutton, 1982: 1464). Thus the lordotic stance causes the apophseal joints to resist the compressive forces generated by loads on the back which may lead to backache and later degenerative changes in the apophseal joints (Adams and Hutton, 1982: 1464). It is postulated that an increased lordosis caused by wearing the scuba diving cylinder can cause impaction of the posterior facets which may lead to backache and degeneration of the apophyseal joints.

In a study conducted by Yang and King (1984) it was found that arthritic facet joints may bare up to 47% of the load transmitted to a full spinal unit. This would be of importance if the scuba diver has degenerated facet joints and uneven weight bearing would occur leading to possible low back pain.

In a study using 105 cadaveric spinal motion segments he was able to deduce which forces caused which type of injury to the lumbar spine. He concluded that, “Small variations in lumbar spine curvature in erect posture are of considerable significance” (Adams and Hutton, 1982: 1464). Loads applied to the lumbar spine in a superior to inferior direction can cause alterations in spinal curvature, these alterations in erect posture can be linked to injury. The scuba diving cylinder applies a superior to inferior load to the lumbar spine and is postulated to cause alterations in the spinal curvature.

Bryner and Moussali (1992) found, through radiographic examination, that there was a weak association between low back pain and changes in lumbar lordosis, in both female and male groups. This association can be of clinical significance as the scuba diving cylinder is postulated to cause changes in the lumbar lordosis.

A diminished lordotic angle in the lumbar spine is seen as a good predictor of low back pain of discal origin (Decuyper and Heijnen, 1988: 30). The study was conducted over a 5-year period studying x-ray films and noting the occurrence of pain and the lordotic angle. The study only involved young women with an occupation of nursing. Statistical analysis revealed that with a decreased lordosis there is a 25% risk of low back pain, with a normal lordosis there is only a 4% risk of low back pain, and with an increased lordosis there is a 8% risk of low back pain, within 5 years in the nursing profession. This is of importance if there is a change in lordotic angle caused by the scuba cylinder and noting if there is an increase or decrease in lordosis. If there is a decrease in the lordosis the low back pain could be linked to discal origin.

Other earlier studies by Kraus (1976) show that mathematical models of the lumbar spine significantly prove that the lumbar lordosis has a direct correlation to injury and failure, showing that flatter spines would tend to fail by flexion and spines with more lordosis would tend to fail by torsion. This is of importance in that when loads are applied to a spine that has a decreased or increased lordosis we are able to identify the probable cause of injury either by torsion or flexion. The study needed to treat the spine as a whole and not a single motion unit, which is not found in *vivo.*

All older studies used in the literature review seem to be the most updated in this field and are still referred to in texts such as Yochum and Rowe (1996: 159-163).

2.2.2 LUMBOSACRAL ANGLE

The lumbosacral angle is the resultant angle formed when two lines meet,

a) A horizontal line is made parallel to the bottom edge of the film, and

b) An oblique line drawn through and parallel to the sacral base.

The lumbosacral angle has a wide range of normal variation from 26 to 57 degrees, with the average being 41 degrees (Yochum and Rowe, 1996: 161).

2.2.2.1 STUDIES ON LUMBOSACRAL ANGLE

An increase in lumbosacral angle has been implicated as a mechanical factor in producing low back pain by increasing the shearing and compressive forces on the lumbosacral joints (Yochum and Rowe, 1996: 161). The wearing of the scuba diving cylinder is postulated to cause an increase in the lumbosacral angle and this increase with the combined weight bearing of the scuba cylinder could lead to shearing and compressive forces in the lumbosacral joints.

2.2.3 LUMBOSACRAL DISC ANGLE

The lumbosacral disc angle is the angle formed by two lines,

a) Drawn parallel and through the inferior endplate of the fifth lumbar vertebra, and

b) Drawn through the superior end plate of the first sacral vertebra (Yochum and Rowe, 1996: 161)

The lumbosacral disc angle has a normal range of 10 to 15 degrees (Yochum and Rowe, 1996: 161), the normal taken at 12.5 for the study. This was done to accommodate the statistical package used in the study as a range cannot be computed, only single figures.

2.2.3.1 STUDIES ON LUMBOSACRAL DISC ANGLE

An increase of more than 15 degrees in the lumbosacral disc angle has been linked to low back pain due to facet impaction (Yochum and Rowe, 1996: 161). This occurs due to the change of weight bearing from the disc to the posterior facets, and as the lumbosacral disc angle increases so do the posterior facets approximate, causing impaction of the facets. It is postulated that the weight of wearing the scuba diving cylinder will increase the lumbosacral disc angle causing facet impaction.

2.2.4 LUMBAR GRAVITY LINE

The lumbar gravity line normally passes through the centre of the third lumbar vertebral body and continues vertically to intersect the sacral base (Yochum and Rowe, 1996: 163). The lumbar gravity line ranges from 10mm posterior to the anterior tip of the sacrum to 10mm anterior to the anterior tip of the sacrum.

2.2.4.1 STUDIES ON LUMBAR GRAVITY LINE

The significance is that if the lumbar gravity line passes anterior to the sacrum by more than 10mm, an increase in the shear stresses in an anterior direction between the lumbosacral apophseal joints may be occurring (Yochum and Rowe, 1996: 163).

This occurs due to the weight bearing forces and the orientation of the L5 - S1 facets as the centre of gravity moves forward the L5 facet pulls up onto the S1 facet causing a shearing force which could lead to injury. It is postulated that the wearing of the scuba diving cylinder will cause an anterior shift in the body's centre of gravity and cause shear stresses on the posterior facet joints. Conversely, a posterior shift in this gravity line may be an indicator of increased weight-bearing forces on the same lumbosacral apophyseal joints, which may also be active in the production of low back pain (Adams and Hutton, 1980: 358). This posterior shift in the centre of gravity causes impaction of the L5 facet onto the S1 facet. This posterior shift in weight bearing on the pars interarticularis causes stress and may lead to spondylolisthesis, but a direct relationship has not been established, only inferred (Jayson, 1983: 338). If there is a posterior shift caused by wearing the scuba diving cylinder, impaction of the posterior facets could occur.

2.3 RESPONSE TO LOADS

The muscular complex of the trunk works as a whole in the stabilization of the lumbar spine during lifting or weight bearing. During load application to the lumbar spine there is a direct correlation between muscle activity and the mass of the load applied. The changes in lordosis and trunk inclination are strictly correlated implying that the nervous system actively co-ordinates the degrees of freedom of the spine (Mitnitski *et al.*, 1998). The ability of the body to stabilize the effect of the weight of the scuba diving cylinder on the lumbar spine is directly related to the neuromuscular response in the individual at the time of wearing the scuba diving cylinder. The degree of lordosis, lumbosacral angle, lumbosacral disc angle, and the lumbar gravity line is controlled by the individual's anatomical structures and the neuromuscular response to the weight of the scuba diving cylinder.

When loads are applied to the lumbar spine, slight flexion may occur (Adams and Hutton, 1985: 625), which flattens the lumbar spine. This flexion has several advantages: flexion improves the transport of metabolites in the intervertebral disc, reduces stresses on the apophseal joints and on the posterior half of the annulus fibrosis, and gives the spine high compressive strength.

The disadvantages are of little significance and it was concluded that it is mechanically and nutritionally advantageous to flatten the spine during sitting and lifting loads (Adams and Hutton, 1985: 625). Many studies conclude that it is better to increase the lordosis during sitting to prevent injury and also that flattening of the spine increases intradiscal pressure (Dinsay *et al.*, 1997: 2574). It is questionable how advantageous flattening of the spine will be while wearing a scuba cylinder, especially if disc lesions are present.

During lifting activities it is seen that asymmetrical lifts can cause increased lateral bending and twisting movements. During asymmetrical lifts EMG signals were greater on the contra lateral side, creating muscle stress during the lift (Aleksiev *et al.*, 1998: 392). The combined effect of twisting and lateral bending can be a major factor in injury to the lower back, thus the scuba cylinder must always be lifted in the midline, as to decrease the chance of injury in the case of asymmetrical lifts.

By looking at the proposed responses of the lumbar spine to the weight of the scuba diving cylinder, we can deduce that the scuba diving cylinder could be a direct cause of mechanical low back pain when standing on land. With correct posture and load response of the body, the chances of mechanical low back injury can be reduced.

2.4 MECHANISM OF INJURY

The mechanism of injury to the lower back normally involves two different mechanisms. The two different mechanisms are namely: rotational and compressive forces (Kirkaldy-Willis and Burton, 1992: 419). The scuba diving cylinder induces a superior to inferior load thus applying compression to the lumbar spine. At any one level the intervertebral joint is made up of three parts, formed by the two posterior facet joints and the intervertebral disc. The changes caused in the angles mentioned in 2.2.1 to 2.2.4 can be linked to injury to all three parts. Compressive forces put more pressure on the intervertebral disc and are more likely to cause injury to the intervertebral disc, while rotational forces apply pressure to the posterior facet joints and are more likely to cause injury to the posterior facet joints (Kirkaldy-Willis and Burton, 1992: 419). Axial torque of the lumbar spine can lead to damage and irritation in the anterior and posterior elements of the lumbar spine, but with torsional loading about the vertical axis, most of the loading will be borne by the posterior elements (White and Panjabi, 1990:384). While wearing the scuba diving cylinder the author postulates that these two mechanisms of injury may be occurring.

In a study conducted on cadaveric lumbar spine intervertebral joints, it was found that in erect standing posture, after a period of sustained loading, the apophyseal joints resisted up to 16% more of the total intervertebral force, compared to the initial force measured in the apophyseal joint (Adams and Hutton, 1980: 358).

This force may very well lead to microtrauma in the lumbar facet joints leading to low back pain. Wearing of the scuba diving cylinder could lead to loss in disc height and allow for increased loading of the intervertebral facet joints.

2.5 MICROLEVEL TRAUMA EVALUATION

On radiological evaluation one cannot always evaluate micro level trauma after load removal on a normal spine (Gallagher *et al.*, 1994: 440). This micro level trauma not seen on radiographs may lead to increased interosseous pressure and this has been linked to a source of low back pain. Thus miniature end plate trauma may be responsible for low back pain in the absence of radiographic findings (Gallagher *et al.*, 1994: 440).

On observation of the scuba divers posture before water entry, whilst wearing the scuba diving cylinder, it is very likely that both compressive and rotational forces are created. The author speculates the exposure of the lumbar spine to forces created by the scuba cylinder may very well increase the risk of mechanical low back pain.

CHAPTER 3: METHODOLOGY

3.1 OBJECTIVES OF THE STUDY.

The objective of this study was to evaluate the effect of a scuba diving cylinder on the static lumbar spine posture, while standing upright on land, to determine if this may have a contribution to causing low back pain.
The objective was measured in terms of the lumbar lordosis, lumbosacral angle, lumbosacral disc angle, and the lumbar gravity line measured from the x-ray films taken in the Technikon Natal radiography department.

3.2 STANDARD OF ACCEPTANCE

The study was open to individuals in the province of Kwazulu Natal who volunteered to participate in the study. The subjects in the study were attracted to the study by personal communication via fellow divers in the Technikon Natal Chiropractic Clinic, scuba diving club (Durban Undersea Club), and by word of mouth through the diving community.

3.2.1 INCLUSION CRITERA

A) The candidates were males, this was to avoid exposure of the female gonads to unnecessary radiation. The male gonads are lower anatomically and the shielding did therefore not necessarily cover the lower lumbosacral area to be x-rayed.

B) All candidates with no history of lumbar spine trauma or current low back pain were allowed to participate in the study.

C) All candidates between the ages of 18 to 45 years were accepted into the study as this is the most common age group of scuba divers (Shannon, 2000).

D) Only candidates who had signed the informed consent form were allowed to participate in the study.

3.2.2 EXCLUSION CRITERA

A) Any candidate found to have an abnormality of the lumbar spine during the physical or radiographic examination was excluded from the study. The abnormalities can be classified as follows: -

I. Congenital anomalies (Yochum and Rowe, 1996: 221-239).

II. Scoliosis (Yochum and Rowe, 1996: 307-323)

III. Skeletal Dysplasias (Yochum and Rowe, 1996: 585-646).

IV. Trauma (Yochum and Rowe, 1996: 695-705).

V. Arthritic disorders (Yochum and Rowe, 1996: 795-965).

VI. Tumours (Yochum and Rowe, 1996: 975-1183).

VII. Infections (Yochum and Rowe, 1996: 1199-1240).

3.3 STUDY DESIGN AND PROTOCOL.

The design was that of a prospective, purposive trial using convenience sampling. The study incorporated 30 volunteers who were accepted according to specific inclusion and exclusion criteria. The volunteers were seen on two occasions, one for the initial consultation and then again for the experimental consultation. Time between the initial and experimental consultation was between 1 to 7 days.

3.3.1 SAMPLING

Thirty subjects were chosen for the study. This number reflected a fair representation of the population when using statistical methods (Thomas, 2001). Each of the thirty volunteers attended an initial consultation and then an experimental consultation, the experimental consultation being done within a few days following the initial consultation.

3.3.2 INITIAL CONSULTATION

The accepted volunteers were given a letter of information (appendix A) to read and the nature of study was carefully explained to them. Once there was full understanding of the study an informed consent form (appendix B) was completed by the subject and signed. Following this a case history and lumbar regional examination were completed to establish agreement with the inclusion and exclusion criteria. The initial consultation was conducted at the Chiropractic Day Clinic at the Technikon Natal.

3.3.3 EXPERIMENTAL CONSULTATION

In order to maintain uniformity a specially designed footplate (appendix h) was made so that each of the volunteers had a base width of 10cm while standing in front of the x-ray bucky, this conformed to normal standing posture (Magee, 1992: 566). Firstly each individual had a neutral erect lateral lumbar spine x-ray. Each individual stood upright with correct postural alignment, ear lobe in line with the tip of the shoulder and high point of the iliac crest (Magee, 1992: 596). For each x-ray, specific skeletal measurements were taken, namely: - a) Lumbar lordosis angle (Appendix E), b) Lumbosacral angle (Appendix F), c) Lumbosacral disc angle (Appendix G), d) Lumbar gravity line (Appendix H). Initial x-ray measurements formed the baseline measurements.

Following the first x-ray, the subject had a second x-ray, now wearing the scuba diving cylinder. The scuba diving cylinder was worn on the subjects back by means of a specific tank harness between the shoulder blades (Appendix J). The subject stood on the same footplate to ensure the same standing posture as the previous x-ray. For each x-ray, the following measurements were done: - a) Lumbar lordosis, b) Lumbosacral angle, c) Lumbosacral disc angle, d) Lumbar gravity line. These measurements formed the experimental measurements.

3.3.4 RELIABILITY OF RESULTS

The measurements taken from each of the x-ray films were checked by the radiologist of the Technikon Natal radiology department, to ensure that the measurements taken by the researcher were accurate.

3.4 ETHICAL CONSIDERATIONS

The rights and the welfare of the volunteers were protected:

- Informed consent was obtained (Appendix B)
- The patients were not coerced into participating in the study
- Information was given to the patients in an understandable language
- The research involved no more than minimal risk
- Confidentiality was maintained
- Participation was voluntary and did not involve financial benefits
- Volunteers were free to withdraw from the study at any stage (Pak and Adams, 1994:37).

As the subjects were pain free and x-rays were done of the lumbar spine, the dosage of radiation was kept to a minimum as to not expose the patients to unnecessary radiation. Gonadal shielding was used.

All subjects had the right to know of any findings that may have been revealed in the study.

3.5 MEASUREMENTS AND OBSERVATION

3.5.1 THE DATA

The study incorporated both primary and secondary data as mentioned below.

3.5.1.1 PRIMARY DATA

The primary data was obtained from the radiographs taken of each of the research subjects. Information gathered from the case history and lumbar regional examination were purely for inclusion and exclusion criteria. Age of each of the volunteers was noted during the initial consultation.

3.5.1.2 SECONDARY DATA

Secondary data was obtained from journal articles, personal communications, radiographic books and publications containing information relevant to the research being conducted.

3.5.2 METHOD OF MEASUREMENT

All measurements taken from each of the x-ray films were measured on a simple protractor in degrees, and right angles draw were from a setsquare, using the edge of the film. Millimetres taken from the lines were measured using a normal ruler. The measurements were repeated by a radiologist for accuracy confirmation.

3.5.3 NORMATIVE RADIOGRAPHIC VALUES

3.5.3.1 LUMBAR LORDOSIS

The average lumbar lordosis normally measures from 50 to 60 degrees (Yochum and Rowe, 1996: 159). The average of 55 degrees was taken as the normal in this study, this is because statistical analysis can only compute single figures and not a broad outline in this study. Other studies on lumbar lordosis have both defined that the normal lumbar lordosis range is between 55 and 65 degrees (Harrison *et al*, 1998), (Cailliet *et al*, 1997).

3.5.3.2 LUMBOSACRAL ANGLE

The lumbosacral angle has a wide range of normal variation from 26 to 57 degrees, with the average being 41 degrees (Yochum and Rowe, 1996: 161).

3.5.3.3 LUMBOSACRAL DISC ANGLE

The lumbosacral disc angle has a normal range of 10 to 15 degrees (Yochum and Rowe, 1996: 161), the normal taken at 12.5 for the study. This was done to accommodate for the statistical package used in the study as a range cannot be computed, only single figures could be computed.

3.5.3.4 LUMBAR GRAVITY LINE

For the study the tip of the anterior tip of the sacrum was considered as 0 millimetres, all lines anterior to or posterior to the anterior tip of the sacrum were recorded in millimetres and all measurements above 10mm were noted as significant.

3.6 THE LOCATION OF DATA

The primary data was obtained from the x-ray films taken during the experimental consultation.

The secondary data was obtained from journals, textbooks and personal communication.

3.7 THE STATISTICAL ANALYSIS

The SPSS statistical package (as supplied by SPSS inc., Marketing Department, 444 North Michigan Avenue, Chicago, Illinois, 60611) was utilised for data entry and analysis.

3.7.1 TREATMENT OF THE DATA

The lumbar lordosis measurements were represented in degrees.

The lumbosacral angle measurements were represented in degrees

The lumbosacral disc angle measurements were represented in degrees

The lumbar gravity line measurements were represented in millimetres
The age of the volunteer was represented in years.

3.8 STATISTICAL METHODS OF DATA ANALYSIS

The sample size of this study was large (30), therefore pair-wise comparisons for all four sets of measurements were made. This was done by using a paired-t test. Once this was established the comparison between the observed angles and the normal angles found in the population (the norm.) was done. To establish this a one-sample t - test was done, each test was done for all four of the results. The level of significance was set at $\alpha = 0.05$. The result is considered significant if the p-value is less than 0.05. The SPSS statistical package was used for the data analysis.

3.8.1 COMPARISON BETWEEN RELATED MEASUREMENTS FOR BOTH X-RAY FILMS

The intragroup comparisons for each of the measurements were done using a paired t-test.

The two-tailed t-test was used to determine weather or not there was any change with regard to the non-weight bearing reading and the weight bearing reading for each of the 4 measurements taken from each film.

HYPOTHESIS TESTING AND THE DECISION RULE FOR THE TWO TAILED PAIRED T-TEST

The null hypothesis (H_o) was the same for both x-rays, it is stated below:

Ho: There is no difference between the non-weight bearing and weight bearing measurements. ($\mu_d = 0$)

The alternative hypothesis (H_a) is the same for both x-rays, it is stated below:

Ha: There is a difference between the non-weight bearing and weight bearing measurements. ($\mu_d \neq 0$)

THE ANALYZED DATA AND THE P-VALUE

The P value (level of significance) is acquired in order to further interpret the results from the data collected once in a spreadsheet format. The P value is defined as the probability of obtaining an outcome as or more extreme than that observed in the study if the null hypothesis were true, if the P value is low we might decide to reject the null hypothesis as incorrect (Coggon, 1995: 66). The data was analysed at the $\alpha = 0.05$ level and the decision rule was applied as follows:

Reject the null hypothesis if the P-value is $< \alpha$

Accept the null hypothesis if the P-value is $\geq \alpha$

HYPOTHESIS TESTING AND THE DECISION RULE FOR THE ONE TAILED T-TEST

The null hypothesis (H_o) was the same for both x-ray films, it is stated below:

Ho: There is no difference between each measurement and that of the norm.

($\mu_1 = \mu_2$)

The alternative hypothesis (H_a) was the same for both groups and is described below:

Ha: There is a difference between each measurement and that of the norm.

Where the measurement is greater than the norm.

($\mu_1 > \mu_2$)

THE ANALYZED DATA AND THE P-VALUE

The data was analysed at the $\alpha = 0.05$ level and the decision rule was applied as follows:

Reject the null hypothesis if the p-value is $< \alpha$

Accept the null hypothesis if the P-value is $\geq \alpha$

The P-value for the one-tailed test is determined using the following formula:

P = Reported P-value / 2 if

Ha is of a form > and Z is positive

Ha is of a form < and Z is negative

P = 1- (reported P- value / 2) if

Ha is of a form > and Z is negative

Ha is of a form < and Z is positive

CHAPTER FOUR: THE RESULTS

4.1 INTRODUCTION

This chapter deals with the results accompanied by the relevant interpretations obtained after statistically analysing the data from the measurement criteria utilized namely:

- Lumbar lordosis
- Lumbosacral angle
- Lumbosacral disc angle
- Lumbar gravity line

4.2 CRITERA GOVERNING THE ADMISSIBILITY OF THE DATA

Data collected from the volunteers who met the inclusion and exclusion criteria of the study were used. Only measurements taken by the researcher that were checked by the Technikon Natal Radiologist were utilized.

4.3 TABLES OF DEMOGRAPHIC DATA

TABLE 4.1 Age distribution

AGE	TOTAL % OF VOLUNTEERS
18-24	16.7
25-31	60
32-38	16.7
39-45	6.6

TABLE 4.2 Gender distribution

Gender	Total number of volunteers
Male	30
Female	0

TABLE 4.3 Race distribution

Race	**Total number of volunteers**
Caucasian	30
Asian	0
Black	0

4.4 TABLES OF STATISTICAL RESULTS

4.4.1 Statistical results comparing non-weight bearing and weight bearing results with that of the norm

TABLE 4.4.1 Comparison of non-weight bearing and weight bearing results and that of the norm for lumbar lordosis

Lumbar lordosis	**Norm.**	**Group mean**
LL 1	55	60.3467
LL 2	55	59.9400

TABLE 4.4.1.1 TEST STATISTICS FOR LUMBAR LORDOSIS

One sample t-test

	Test Value = 55					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence interval of the difference	
					Lower	Upper
LL 1	2.600	29	.015	5.346	1.1403	9.5530
LL 2	2.332	29	.027	4.9400	.6075	9.2725

α = 0.05

For the non-weight bearing reading the null hypothesis was rejected, implying that there was a statistically significant change between the non-weight bearing measurement and that of the norm. (The measurement was greater than that of the norm).

For the weight bearing reading the null hypothesis was rejected, implying that there was a statistically significant change between the weight bearing measurement and that of the norm. (The measurement was greater than that of the norm).

The degree of lumbar lordosis was still within normative parameters and is of no radiographic significance in terms of predisposition to injury.

TABLE 4.4.2 Comparison of non-weight bearing and weight bearing results and that of the norm for lumbosacral angle

Lumbosacral angle	**Norm.**	**Group mean**
LSA 1	41	43.1850
LSA 2	41	45.7633

TABLE 4.4.2.1 TEST STATISTICS FOR LUMBOSACRAL ANGLE

One sample t-test

	Test Value = 41					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence interval of the difference	
					Lower	Upper
LSA 1	1.192	29	.243	2.1850	-1.5634	5.9334
LSA 2	3.129	29	.004	4.7633	1.6498	7.8768

$\alpha = 0.05$

For the non-weight bearing reading the null hypothesis was accepted, implying that there was no change between the non-weight bearing measurement and that of the norm.

For the weight bearing reading the null hypothesis was rejected, implying that there was a statistically significant change between the weight bearing measurement and that of the norm. (The measurement was greater than that of the norm).

The degree of lumbosacral angle was still within normative parameters and is of no radiographic significance of predisposition to injury.

TABLE 4.4.3 Comparison of non-weight bearing and weight bearing results and that of the norm for lumbosacral disc angle

Lumbosacral disc angle	**Norm.**	**Group mean**
LSDA 1	12.5	20.1283
LSDA 2	12.5	17.7733

TABLE 4.4.3.1 TEST STATISTICS FOR LUMBOSACRAL DISC ANGLE

One sample t-test

	Test Value = 12.5					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence interval of the difference	
					Lower	Upper
LSDA 1	8.712	29	.000	7.6283	5.8374	9.4192
LSDA 2	4.084	29	.000	5.2733	2.6324	7.9143

α = 0.05

For the non- weight bearing reading the null hypothesis was rejected, implying that there was a statistically significant change between the non-weight bearing measurement and that of the norm. (The measurement was greater than that of the norm).

For the weight bearing reading the null hypothesis was rejected, implying that there was a statistically significant change between the weight bearing measurement and that of the norm. (The measurement was greater than that of the norm).

The degree of lumbosacral disc angle was still within normative parameters and is of no radiographic significance in predisposition to injury.

TABLE 4.4.4 Comparison of non-weight bearing and weight bearing results and that of the norm for lumbar gravity line

Lumbar gravity line	Norm.	Group mean
LGL 1	0	19.2433
LGL 2	0	11.9582

TABLE 4.4.4.1 TEST STATISTICS FOR LUMBAR GRAVITY LINE

One sample t-test

	Test Value = 0					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence interval of the difference	
					Lower	Upper
LGL 1	7.317	29	.000	19.2433	13.8647	24.6220
LGL 2	6.701	29	.000	14.6300	10.1647	19.0953

α = 0.05

For the non-weight bearing reading the null hypothesis was rejected, implying that there was a statistically significant change between the non-weight bearing measurement and that of the norm. (The measurement was greater than that of the norm).

For the weight bearing readings the null hypothesis was rejected, implying that there was a statistically significant change between the weight bearing measurement and that of the norm. (The measurement was greater than that of the norm).

The measurement of the lumbar gravity line was still within normative radiographic parameters and of minimal radiographic significance in terms of predisposition to injury.

4.4.2 STATISTICAL RESULTS OF INTRAGROUP COMPARISONS WITH REGARDS TO NON-WEIGHT BEARING AND WEIGHT BEARING READINGS

TABLE 4.4.5 Intragroup comparison of Lumbar lordosis with regards to non-weight bearing and weight bearing readings

Lumbar lordosis	**Group mean**
Non-weight bearing	60.3467
Weight bearing	59.9400

TABLE 4.4.5.1 TEST STATISTICS FOR LUMBAR LORDOSIS

Paired t-test

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. Error mean	95% Confidence interval of the difference: Lower	95% Confidence interval of the difference: Upper			
Pair 1	LL 1 LL 2	.4067	7.2343	1.3208	-2.2946	3.1080	.308	29	.760

α = 0.05

The null hypothesis was accepted, implying that there was no difference between the non-weight bearing and weight bearing measurements for lumbar lordosis.

TABLE 4.4.6 Intragroup comparison of Lumbosacral angle with regards to non-weight bearing and weight bearing results

Lumbosacral angle	**Group mean**
Non- weight bearing	43.1850
Weight bearing	45.7633

TABLE 4.4.6.1 TEST STATISTICS FOR LUMBOSACRAL ANGLE

Paired t-test

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. Error mean	95% Confidence interval of the difference				
					Lower	Upper			
Pair 1	LSA 1 LSA 2	-2.5783	5.9915	1.0939	-4.8159	-.3411	-2.357	29	.025

α = 0.05

The null hypothesis was rejected, implying that there was a statistically significant difference between the non-weight bearing and weight bearing measurements for lumbosacral angle.

The difference in measurement between the non-weight bearing and weight bearing measurement was still within normal radiographic parameters and there is minimal risk of predisposition to injury.

TABLE 4.4.7 Intragroup comparison of Lumbosacral disc angle with regards to non-weight bearing and weight bearing results

Lumbosacral disc angle	**Group mean**
Non-weight bearing	20.1283
Weight bearing	17.7733

TABLE 4.4.7.1 TEST STATISTICS FOR LUMBOSACRAL DISC ANGLE

Paired t-test

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. Error mean	95% Confidence interval of the difference				
					Lower	Upper			
Pair 1	LSDA 1 LSDA 2	2.3550	5.9981	1.0951	.1153	4.5947	2.15	29	.040

α = 0.05

The null hypothesis was rejected, implying that there was a statistically significant difference between the non-weight bearing and weight bearing measurements for the lumbosacral disc angles.

The difference in the measurement between the non-weight bearing and weight bearing angle was within normal radiographic parameters.

TABLE 4.4.8 Intragroup comparisons for lumbar gravity line with regards to non-weight bearing and weight bearing results

Lumbar gravity line	**Group mean**
Non-weight bearing	19.2433
Weight bearing	11.6300

TABLE 4.4.8.1 TEST STATISTICS FOR LUMBAR GRAVITY LINE

Paired t-test

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. Error mean	95% Confidence interval of the difference				
					Lower	Upper			
Pair 1	LGL 1 LGL 2	4.6133	15.6077	2.8496	-1.2147	10.4414	1.619	29	.116

α = 0.05

The null hypothesis was accepted, implying that there was no statistically significant difference between the non-weight bearing and weight bearing measurements for the lumbar gravity line.

CHAPTER FIVE: DISCUSSION OF THE RESULTS

5.1 INTRODUCTION

This chapter involves the discussion of the results after statistical analysis obtained from the x-ray films.

The results are discussed in two parts, (1) comparing the results with that of the already established norms, and (2) comparing the results of the non-weight bearing readings with the weight bearing readings.

The non-weight bearing reading established the baseline measurements, the weight bearing reading formed the experimental measurements. Once these were established the evaluation between the results and the literature based normative values could be done. The increase or decrease in the measurements taken would give an indication of the effect the scuba diving cylinder has on the lumbar spine.

5.2 INTERGROUP COMPARISON OF NON-WEIGHT BEARING AND WEIGHT BEARING READINGS TO THAT OF THE NORM

The objective data is obtained from the experimental consultation and the already established data found in books and journals.

The statistical data can be found in tables 4.4.1 to 4.4.4

5.2.1 LUMBAR LORDOSIS

5.2.1.1 Non-weight bearing readings

Statistical analysis, using the SPSS statistical package, of the lumbar lordosis revealed that there was a statistically significant difference between the non-weight bearing mean to that of the established norm.

Yochum and Rowe (1996) describe that the normal lumbar lordosis has a range of between 50 to 60 degrees, and Harrison *et al.* (1998) defined the normal lumbar lordosis has a range of 55-65 degrees. Fernand and Fox (1985) describes a lumbar lordosis above 68 degrees as hyperlordotic. The test mean of the lumbar lordosis without the scuba diving cylinder was 5.35 degrees greater than the norm. According to literature based normative ranges the non-weight bearing measurement was still within radiological norms.

5.2.1.2 Weight bearing readings

Statistical analysis of the lumbar lordosis revealed that there was a statistically significant change between the weight-bearing mean and that of the established norm, implying that the scuba diving cylinder caused a change in the lumbar lordosis.

The test results for the lumbar lordosis with the scuba diving cylinder was 4.9 degrees greater than the norm, which is still within normal radiological parameters. The weight bearing mean was 0.45 degrees less than the non-weight bearing mean which could be caused by flattening of the spine to allow for a weight shift to the anterior part of the spinal column. This will also reduce stresses on the apophyseal joints and posterior annulus. This slight flattening also gives a higher compressive strength to the spinal column (Adams and Hutton, 1985:625). It was observed that 56.6% of the volunteers had a decrease in lordosis while only 43.4% had an increase in lordosis as a result of wearing the scuba diving cylinder. This may be linked to flattening of the lumbar spine during weight bearing as described by Adams and Hutton (1985).

5.2.2 LUMBOSACRAL ANGLE

5.2.2.1 Non–weight bearing readings

Statistical analysis of the lumbosacral angle revealed that there was no statistically significant change between the non-weight bearing mean to that of the established norm.

The normal variation found for the lumbosacral angle was between 26 to 57 degrees, with the average being 41 degrees (Yochum and Rowe, 1996:161). The test results for lumbosacral angle were within literature based normative ranges, and of little radiological significance.

5.2.2.2 Weight bearing readings

Statistical analysis for lumbosacral angle revealed that there was a statistically significant change between the weight bearing mean to that of the established norm, implying that the scuba diving cylinder has caused a change to the lumbosacral angle.

The test results with the scuba diving cylinder. Showed an increase of 4.8 degrees when compared to the norm. This measurement was still within the normal range and was of no radiological significance. Lumbosacral angles above 57 degrees are implicated in mechanical low back pain (Yochum and Rowe, 1996: 161).

5.2.3 LUMBOSACRAL DISC ANGLE

5.2.3.1 Non-weight bearing readings

Statistical analysis of the lumbosacral disc angle revealed that there was a statistically significant change between the non-weight bearing mean and that of the established norm.

The normal range of the lumbosacral disc angle was found to be between 10 to 15 degrees (Yochum and Rowe, 1996:161). The test results of the lumbosacral disc angle without the scuba diving cylinder was radiologically greater than the norm. Angles above 15 degrees have been implicated in low back pain due to facet impaction (Yochum and Rowe, 1996: 161). The lumbosacral disc angle was 20.1 degrees for non-weight bearing which is

5.1 degrees above the angle implicated in facet impaction. Reasons for such a high lumbosacral disc angle for the study group was unexplainable but could be linked to the fact that all volunteers had to stand in a specific posture conforming to normal standing posture as described by Magee (1992). Also all volunteers had no low back pain during the study.

5.2.3.2 Weight bearing readings

Statistical analysis of the lumbosacral disc angle revealed that there was a statistically significant change between the weight bearing measurement and that of the established norm, implying that the scuba diving cylinder has caused a change in the lumbosacral disc angle.

The lumbosacral disc angle with the scuba diving cylinder on was 17.8 degrees which was 2.8 degrees above the 15 degrees implicated in facet impaction. The test results for weight bearing were 2.3 degrees less than the non-weight bearing measurement, which could be caused by flattening of the spine to allow for a weight shift to the anterior part of the spinal column. This will also reduce stresses on the posterior apophyseal joints and posterior annulus therefore reducing the impaction on the posterior facets during weight bearing. This slight flattening also gives a higher compressive strength to the spinal column (Adams and Hutton, 1985:625). This shift of the lumbosacral disc angle closer to the norm may be implying that the neuromuscular response of the body compensates for the load of the scuba diving cylinder and thus tries to reduce the risk of injury to the lower back.

5.2.4 LUMBAR GRAVITY LINE

5.2.4.1 Non-weight bearing readings

Statistical analysis of the lumbar gravity line revealed that there is a statistically significant change between the non-weight bearing mean to that of the already established norm.

The lumbar gravity line ranges from 10mm posterior to the anterior tip of the sacrum to 10mm anterior to the anterior tip of the sacrum (Yochum and Rowe, 1996:163). The mean for the lumbar gravity line without the scuba diving cylinder was 11.59mm posterior to the anterior tip of the sacrum. Studies have implied that this could cause increased weight bearing on the lumbosacral facet joints which may lead to low back pain (Yochum and Rowe, 1996: 163). The possible reason for the lumbar gravity line to be posterior to the anterior tip of the sacrum by 11.59mm may be linked to the fact that all volunteers had to stand in a specific posture conforming to normal standing posture as described by Magee (1992). This could have caused the lumbar gravity live to be slightly posterior if the volunteers had to stand more erect than normal.

5.2.4.2 Weight bearing readings

Statistical analysis of the lumbar gravity line revealed that there is a statistically significant change between the weight bearing measurement to that of the established norm, implying that the scuba diving cylinder has caused a change to the lumbar gravity line.

The mean for the lumbar gravity line when wearing the scuba diving cylinder was 2.89mm greater than the norm. The lumbar gravity line was anterior to the anterior tip on the sacrum showing that there was anterior shift in the bodies centre of gravity to compensate for the wearing of the scuba diving cylinder. The measurement was within normative radiological parameters.

5.3 INTRAGROUP COMPARISON BETWEEN NON-WEIGHT BEARING AND WEIGHT BEARING

The objective data obtained is comprised of the measurements taken during the experimental consultation.

The statistical data can be found in table’s 4.4.5 to 4.4.8

5.3.1 LUMBAR LORDOSIS

Statistical analysis of the lumbar lordosis revealed that there was no statistically significant difference between the non-weight bearing mean to that of the weight bearing mean.

The wearing of the scuba diving cylinder caused a small decrease in the lumbar lordosis. The group mean for non-weight bearing was 60.3467 and for weight bearing it was 59.94. The weight bearing mean was 0.45 degrees less than the non-weight bearing mean, which could be caused by flattening of the spine to allow for a weight shift to the anterior part of the spinal column. This will also reduce stresses on the apophyseal joints and posterior annulus. This slight flattening also gives a higher compressive strength to the spinal column (Adams and Hutton, 1985:625). It was observed that 56.6% of the volunteers had a decrease in lordosis while only 43.4% had an increase in lordosis as a result of wearing the scuba diving cylinder. This flattening of the spine may be linked to the research conducted by Adams and Hutton (1985) on the advantages of flattening the spine during weight bearing.

5.3.2 LUMBOSACRAL ANGLE

Statistical analysis of the lumbosacral angle revealed that there was a statistically significant difference between the non-weight bearing mean and weight bearing means, implying that there is a change caused by the effect of the scuba diving cylinder on the lumbosacral angle.

The lumbosacral angle non-weight bearing mean was 43.1850 degrees and the weight bearing mean was 45.7633 degrees. There was a 2.61 degree increase observed from the non-weight bearing mean to the weight bearing mean. The increase was within normative radiological parameters and of little radiological significance.

5.3.3 LUMBOSACRAL DISC ANGLE

Statistical analysis of the lumbosacral disc angle revealed that there was a statistically significant difference between the non-weight bearing and weight bearing means, implying that there is a change caused by the effect of the scuba diving cylinder on the lumbosacral disc angle.

The lumbosacral disc angle non-weight bearing mean was 20.1283 degrees and the weight bearing mean was 17.7733 degrees. There was a 2.3 degree decrease in the lumbosacral disc angle from non- weight bearing to weight bearing. This decrease in the weight bearing lumbosacral disc angle is seen as advantageous as there is less impaction of the posterior facets. The shift in the load of the scuba diving cylinder will move anteriorly decreases stresses on the posterior annulus and posterior facets.

5.3.4 LUMBAR GRAVITY LINE

Statistical analysis of the lumbar gravity line revealed that there was no statistically significant difference between the non-weight bearing mean to that of the weight bearing mean, implying that the scuba diving cylinder does not effect the lumbar gravity line from non-weight bearing to weight bearing.

The lumbar gravity line non-weight bearing mean was 11.59mm posterior to the anterior tip of the sacrum and the weight bearing mean was 2.89mm anterior. Radiological analysis revealed a change of 14.48mm in an anterior direction as a result of wearing the scuba diving cylinder.

The shift anteriorly of the lumbar gravity line was important as the stresses on the posterior elements of the lumbar vertebrae were reduced. The lumbar gravity line moved closer of the anterior tip of the sacrum during weight bearing, thus placing the body's centre of gravity in a position to compensate for the weight of the scuba diving cylinder. The anterior shift of the lumbar gravity line, while wearing the scuba diving cylinder, may be linked to the forward tilting of the body to compensate for the scuba diving cylinder.

5.4 SUMMARY OF FINDINGS

The results of the study conformed to the literature based radiographic normative values. The values for lumbosacral disc angle and lumbar gravity line for non-weight bearing were slightly greater than the normative values but this can be linked to the volunteers having to conform to normal standing posture as described by Magee (1992: 566), rather than standing in a position that is preferred by the volunteer. A review of related literature has revealed that certain measurements are indicators for low back pain. For lumbar lordosis, angles above 68 degrees were seen as hyperlordotic, and in weight bearing, can be associated with low back pain. For the lumbosacral angle, angles above 57 degrees were implicated in the development of low back pain. For the lumbosacral disc angle, angles above 15 degrees were implicated in the development of low back pain. For the lumbar gravity line any measurement anterior or posterior to the anterior tip of the sacrum by 10mm was implicated in the development of low back pain.

5.5 OTHER FINDINGS

There were 2 subjects that on radiological examination had to be excluded from the study. A grade one spondylolisthesis was found in one subject. The other subject presented with 6 lumbar vertebrae.

5.6 OBJECTIVE DATA RELIABILITY STUDIES

A study conducted by Asplund (1996) to evaluate the reliability and reproducibility of lumbar lordosis measurements showed good intraobserver and interobserver reliability. Intraobserver reliability coefficients ranged from 0.83 to 0.92, indicating excellent reproducibility. Interobserver reliability coefficients ranged from 0.83 t0 0.92. High overall and pair wise agreement between observers was present. Ninety-two percent of repeat measures were within 10 degrees (Asplund, 1996). The factors that could affect the reproducibility of measurements include end vertebra selection and vertebral end plate architecture.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS.

6.1 CONCLUSION

The results indicated that the scuba diving cylinder causes minor changes on static lumbar spine posture. Minor changes were seen in all four measurements taken. There was a decrease in three of the measurements as a result of wearing the scuba diving cylinder. The lumbar lordosis decreased by 0.4 degrees, the lumbosacral disc angle decreased by 2.3 degrees, and the lumbar gravity line shifted anteriorly by 14.48mm on average, indicating that the body is compensating for the load of the scuba diving cylinder. The compensation of the body tends to be in a position more favourable for weight bearing according to literature based norms and studies involving loads on the lumbar spine. During weight bearing the group mean, on average, was closer to literature-based norms, which could be linked to the fact that correct standing posture was maintained during the x-ray procedure.

The study revealed certain limitations. The volunteers had to stand erect to conform to correct standing posture as described by Magee (1992). This set a precedent. As, to the authors knowledge, no similar research had been conducted. This was a limitation, as the effect of the scuba diving cylinder on the volunteers own posture was not evaluated.

Results caused by movement, during loading on the lumbar spine, are unknown so static evaluation was performed. This was also a limitation as injury to the lumbar spine is more likely to occur, during loading, when twisting and bending movements occur, as in walking, lifting, and getting into the water, which scuba divers may do with the scuba diving cylinder on.

The study has tried to define the cause of low back pain in scuba divers as a direct result of wearing a scuba diving cylinder during erect standing on land. The study defines that wearing a 12-litre aluminium scuba diving cylinder, during static erect posture on land, does not cause sufficient changes in the static lumbar spine, on radiographic analysis, to be of any clinical significance. It also indicates that low back pain, related to wearing a scuba diving cylinder, is at least, not simply due to the static postural changes which occur. Other factors such as previous history of low back trauma or pain, poor posture, time of the tank on the back, weak low back muscles, and poor fitting equipment are possible causes of low back pain, in this situation, an warrants further investigation.

6.2 RECOMMENDATIONS

The following recommendations are made for future studies:

Randomisation

Stratified randomisation could be used, taking into account factors such as age, height, weight, body morphology, and race group. This could allow for more valid results.

Sex

The inclusion of females in the study, would allow for a more valid result for the population.

Time

The time the scuba diving cylinder is worn on the back could be increased as muscle fatigue, creep, and loss of disc height increase the chances of low back injury.

Free standing posture

The volunteers could be allowed to stand in a manner, which suits them, and not conform to normal standing posture (Magee, 1992: 566). Poor posture combined with the weight of the tank on lumbar spine may be implicated in the development of low back pain.

Movement

An injury in the lumbar spine is more likely to occur when there is asymmetry in the load applied (Kirkaldy – Willis and Burton, 1992: 419). Asymmetry is more likely to occur when the subject is moving with the scuba diving cylinder *i.e.* walking on uneven surfaces such as beach sand. Future studies could include specific standing plates (one leg higher than the other) to allow for uneven weight distribution to the lower limbs.

Inclusion of pain subjects

The presence of low back pain and or injury to the lumbar spine would cause the spine to react differently during weight bearing.

Sample size

A larger sample size could be selected to improve the validity of the research.

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