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A Review of Noninvasive Tools Used for Measuring Flexion of the Lumbar Spine

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A REVIEW OF NONINVASIVE TOOLS USED

FOR MEASURING FLEXION OF THE LUMBAR SPINE

by

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This Independent Study, submitted by Mary E. Johnson in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

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Department Physical Therapy

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Signature Mary E. Johnson

Date 4-15-94

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ABSTRACT

The purpose of this study is to compare the reliability, validity, and ease of administration for various noninvasive tools used for measuring flexion of the lumbar spine. A synopsis of several clinical techniques is offered: Schober's technique, modified Schober, modified modified Schober, fingertip to floor, modified fingertip to floor, goniometer, single inclinometer, double inclinometer, and flexicurves. The results were variable for the different techniques with each having its own inherent advantages and disadvantages. Ultimately, the clinician can weigh the information presented when choosing a technique. It appears that a true gold standard has yet to be described. Therefore, it is the intention of this review to stimulate further research which will allow for greater accuracy in the measurements of flexion in the lumbar spine.

CHAPTER I

INTRODUCTION

Low back pain is a condition that has troubled mankind for centuries. It is generally thought to be one of the major public health problems facing industrialized societies today.[1] Most studies have found that approximately 80% of people are affected by low back pain at some time in their lives, with the first episodes occurring most often between 20 - 40 years of age.[2] As this occurrence is primarily during an individual's most productive years, it is a disorder that causes major social and economic consequences.

Low back pain is a primary cause of morbidity, disability, limitation of activity, and economic loss.[2] The costs are economically staggering in terms of lost wages, disability awards and payments, and the total cost of treatment. The annual cost of low back pain is estimated to be $16 billion.[3] In the United States, it is now the leading cause of work compensation payments. The loss of productivity is estimated to be approximately eight hours per year per worker for a total of 540 million days of lost work.[4] The cost of low back pain also affects an individual's quality of life because a person who is experiencing back pain must limit physical activity and is unable to perform activities at a premorbid level. This limitation affects the psychosocial status and can cause severe stress to both the individual and family.

A correlation between low back pain and reduced lumbar motion has been reported by several authors, but has been difficult to demonstrate due to measurement difficulties when determining the limitation of motion.[5] Many studies have shown reliability and validity with measurements of extremity movements, but the measurement of trunk motion has proven to be more complex. Although observer error is present with any clinical examination, it is particularly common in the measurement of trunk flexibility. Unlike the recording of other joint motions, the spine is still being assessed largely by clinical observation and subjective impression.[6] Some of the relatively unrefined subjective methods for determining spinal mobility include the use of rating scales, descriptions of the percentages of movement, and visual estimations of the degree of spinal movement without assigning any numerical values. These commonly employed methods are based on observation rather than on objective data. Simple "observation" has revealed discrepancy rates of up to 30%[7] and it is inadequate for describing spinal motion. This widespread traditional practice of assessing spinal mobility subjectively has overshadowed more accurate measurement of spinal movement by objective techniques.[8] Because determination of the degree of impairment and disability in patients with chronic back pain may depend primarily on spinal flexibility, there is a need for consistent and accurate clinical measurements.[9]

Spinal mobility measurements are essential during the physical evaluation of a patient with low back pain to determine the degree of disability, quality of movement, rate of improvement, and to select appropriate treatment techniques. The measurement of lumbar mobility is a routine clinical procedure for patients experiencing low back pain, with flexion being the most commonly assessed motion.[7] Several clinical techniques for measuring flexion of the lumbar spine have been described. Although radiographic methods are the most objective, the high cost and the risk of exposing patients to radiation make noninvasive methods preferable in clinical work. Noninvasive measurements include the use of tape measures, flexible rulers, standard goniometers, inclinometers, and other special instruments.

A critique of these measurement tools questions the ease of administration, validity, and the reliability of the measurements produced. Numerous studies[10-12] have suggested that many of these methods require special equipment not commonly found in most physical therapy clinics. These tools need to be appropriate for use in the clinic where important concerns are for quick and accurate measurements.

Test validity is the ability of a testing procedure to measure what it is intended to measure and involves three components: content, criterion-relatedness, and construct. Specifically, content validity is the systematic examination of the items contained within a test that are used to determine the effectiveness of the representative sample of behavior that is being measured.

Criterion relatedness involves predictable and concurrent measures. It is the comparison of the instrument used to what would be considered a gold standard. Construct validity is the extent to which a test measures a theoretical trait or its ability to differentiate between a disabled and nondisabled population.[13] Knowledge of the validity of the measurement tool is essential in the evaluation of spinal function. Bending of the lumbar spine is a complex movement combining intersegmental motion and hip motion which makes measurement somewhat difficult. Questions raised concerning the validity of these measurement tools are due to their failure to isolate lumbar flexion from a number of different variables which can influence the final measurement.[14] Instead of measuring strict lumbar motion, gross movements of all of the joints are measured, with the combined influences of hip flexion, hamstring extensibility, and arm length.

A measurement procedure is considered reliable if it produces stable, consistent measurements through repeated measurements by one tester (intrarater reliability), and if consistency exists between two or more testers (interrater reliability). It is important to know the reliability of a measurement tool to distinguish real changes from variations in measurement.[15] The potential sources of error in surface measurement are numerous and include the particular choice of reference landmarks, intraobserver and interobserver variations in technique, choice of the measurement tool, and potential combined effects of the above.[16] In addition, differences in measurement of spinal movement can be attributed to the difficulty in the alignment of the measuring device,[17] to individual differences in bony landmarks such as spinal abnormalities,[18], to the difficulty in the palpation of bony landmarks,[10], and to the presence of excess subcutaneous tissue. Inconsistent palpation can produce inaccurate landmark identification which results in measurement variability. Several studies have shown that the presence of excess soft tissue affects the accuracy in the palpation of bony landmarks.[10,17-20] A study by Frost et al[10] suggests that more specific definitions of landmarks would decrease the amount of error. In their study, the authors stated that a 1-2 centimeter difference between the proximal and most distal aspect of the spinous process may have accounted for as much as 50% of the error. Similarly, a study by Chiarello and Savidge[11] found that prior training in palpatory techniques improves the reliability of lumbar measurements.

Studies of the relationship between lumbar sagittal mobility and low back pain require a technique which is valid, repeatable, and suitable for use in the clinic.[21] Accurate measurements of range of motion are not only important for guiding therapeutics, but also for effective communication between therapists and physicians. These measurements are also valuable in documentation to facilitate reimbursement from third party payers.

This paper is a literature review of the various noninvasive tools used for measuring flexion of the lumbar spine. The primary purpose is to compare the reliability, validity, and ease of administration of such techniques. The anatomy and biomechanics of the lumbar spine will be reviewed as this knowledge is of paramount importance to ensure the proper use of these instruments in obtaining accurate measurements. This literature review is intended to provide the therapist with a resource of those techniques that are appropriate for use in the clinic and that will allow for a more objective measurement of the lumbar spine.

CHAPTER II

ANATOMY/BIOMECHANICS

The spine serves three basic functions: to protect the vital neural elements, to transmit load, and to allow motion. The typical vertebra consists of a body and a neural arch which enclose an area known as the vertebral canal. This canal serves the critical function of encasing and protecting the spinal cord. The lumbar spine is a structural link between the thorax and the pelvis. It acts as a reciprocal junction of force absorption by supporting and distributing the weight of the upper body to the pelvis and lower extremities, and by transmitting the forces from the lower extremity upwardly to attenuate ground reaction forces. The structure of the human spinal column also allows flexibility of the trunk and helps the body to retain an upright position by means of coordinated action between bones, muscles, and ligaments.[22]

The spinal column consists of four normal curves. The primary curves are referred to as kyphotic curves and are convex posteriorly. These curves are present at birth as the entire column assumes a "C" shape, and are still apparent in the thoracic and sacral areas of the adult.[23] The secondary curves develop because of gross motor maturation as the upright posture is assumed. They are referred to as lordotic curves with their convexity anterior and are apparent in the cervical and lumbar areas of the adult. The cervical lordosis develops at about three months of age, or when the infant starts to hold up his head. The lumbar curve begins to develop at about one year, or when walking begins, and is complete at about ten years of age (Figure 1). Lumbar lordosis appears to be an adaptation to upright stance with straight knees.[24] To bring the center of gravity of the trunk above the hips, the lumbar spine must bend backward on itself. The cervical lordosis likewise brings the center of gravity of the head posteriorly. All of the these curves serve as a mechanical basis to give the spinal column increased flexibility and to augment shock absorption capacity, while maintaining adequate stiffness and stability at the intervertebral joint level.[24] Kapanji believes that these curvatures increase the resistance of the vertebral column to axial compression forces ten times that of a straight column.[24]

The spine allows for three degrees of freedom: flexion and extension, lateral flexion, and rotation. The type and range of movements possible in each region of the spine depend on the shape and direction of the articular facets and on the thickness of the intervertebral discs. The primary purpose of the facets is to guide intersegmental motion of the functional unit which consists of two vertebrae and their intervening soft tissues. The facet orientation determines the type of motion possible at any level of the spine. The articular facets for L_{1-4} and the superior facets of L_5 lie in the sagittal plane, while the inferior facets of L_5 and superior facets of S_1 lie in the horizontal plane.[23]

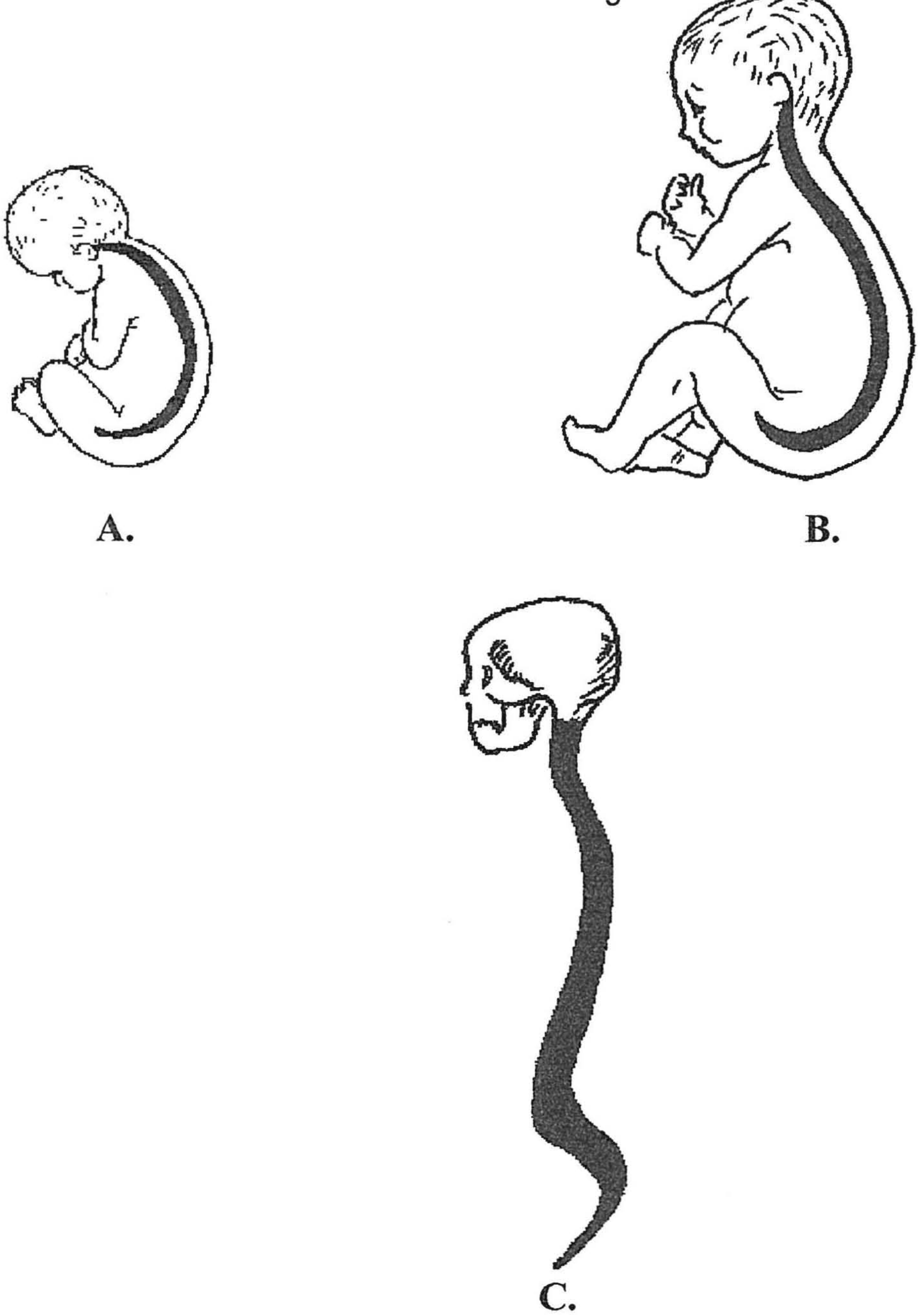

Figure 1. Development of Spinal Curves. A. newborn infant; B. baby holds head up steadily (3 - 4 months); C. adult.

The articular surfaces of the superior articular processes face medially and posteriorly, and those of the inferior articular processes face anteriorly and laterally (Figure 2). In addition, movement between adjacent vertebrae is maximal where the disc is thickest, and least where the disc is thinnest. Therefore, the motion of flexion is relatively free in the lumbar spine due to the direction of the facets and to the large size of the discs.

Total spinal flexion is estimated to be 70 degrees,[25] with the majority of the motion occurring in the lower segments. Seventy percent of the amount of lumbar flexion occurs between L_5-S_1, 20% between $L_{4\text{-}5}$, and 10% over the final three segments of $L_{3\text{-}2\text{-}1}$.[23] Further motion is produced by tilting the pelvis posteriorly. At the end of flexion, the lumbar spine is flattened from its lordotic curve to a straight position.

Motion of the spine is produced by the coordinated action of muscles surrounding the trunk. The agonistic muscles initiate and carry out the motion, while the antagonistic muscles control and modify it. The muscles involved in flexion of the lumbar spine include the quadratus lumborum, the psoas major and minor, the erector spinae musculature, and the muscles of the abdominal wall; the internal and external obliques, and the rectus abdominus. The movement of flexion is initiated by the abdominal muscles and the vertebral portion of the psoas muscle. Further flexion is produced by the weight of the upper body which is controlled by a gradual increase in eccentric activity of the erector spinae musculature and the thoracolumbar fascia.[26] Together, these

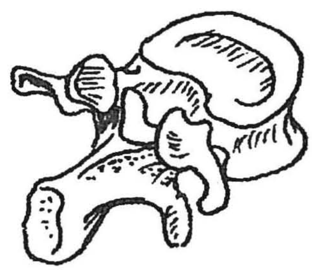

Figure 2. Typical lumbar vertebrae

two structures stabilize the trunk as gravity pulls it down. Once full flexion is achieved, the erector spinae muscles become inactive and are fully stretched. In this elongated position, the musculature, the thoracolumbar fascia, and the posterior ligaments have become taut and passively counteract the forward bending moment.[26] The posterior hip musculature is active in controlling the tilting of the pelvis as the spine is flexed.

Several ligaments limit flexion of the lumbar spine. The supraspinous ligament is a strong fibrous cord which connects the tips of the vertebral spinous processes from the seventh cervical vertebrae to the sacrum. This ligament is broadest in the lumbar region. The interspinous ligaments are short and strong running between adjacent spinous processes, while the ligamentum flavum connects adjacent laminae. The posterior longitudinal ligament is a continuous band extending the entire length of the spine along the posterior bodies of the vertebrae (Figure 3). This ligament is broadest in the cervical area and narrowed to approximately half of the width in the lumbar area.[23]

It is evident that the lumbar spine is very complex with many structures influencing its motion. Functional motion of the spine is always a combined action of several segments. The muscles of the trunk which are involved in motion provide extrinsic stability of the spine, and the ligaments and discs provide intrinsic stability.[26] In summary, all of the surrounding structures of the spine act together to provide stability, to protect the spinal cord, and to allow spinal motion.

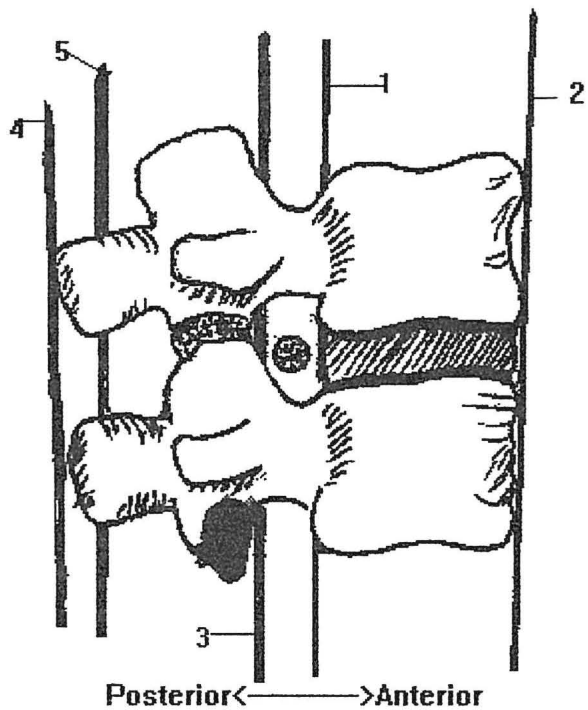

Figure 3. Functional unit of the lumbar spine with spinal ligaments.
1. posterior longitudinal ligament; 2. anterior longitudinal ligament;
3. ligamentum flavum; 4. supraspinous ligament; 5. interspinous ligament.

CHAPTER III

TAPE MEASURES

Several methods have been described for the use of tape measures in recording the measurements of lumbar flexion. Some of the advantages of this method are that it is simple to use, inexpensive, and is not harmful to the patient. In addition, the American Academy of Orthopedic Surgeons suggests the use of the tape measure as an accurate method of measuring the true motion of spinal flexion because of its ability to conform to spinal curves.[27] The tape measurements most commonly used in the clinical setting include the skin distraction method originally described by Schober,[28] the distance measured from the fingertip to the floor,[10] and modifications of the above.[29-31]

Schober's Technique

The skin distraction technique originally described by Schober in 1937[28] involved the use of a tape measure held directly over the spine at the lumbosacral junction (L_5-S_1), and 10 centimeters above while the subject stood in a neutral position. The subject was then instructed to move into full lumbar flexion, and the increase in the distance between the two marks was recorded to give an estimate of lumbar spinal flexion. Schober's early article indicated no data on consistency of results with repeated testing. However, Fitzgerald et al[12] studied the interrater reliability of Schober's original method of skin distraction. In this study, two observers independently took three measurements of lumbar flexion of 17 physical therapy students. While the subjects were positioned standing erect with their feet approximately shoulder width apart, the observers located the most superior aspects of the iliac crests by palpation and placed a mark over the corresponding spinal level (L_4-L_5). A second mark was placed 10 centimeters above the first reference point. Each subject was then instructed to bend forward as far as possible while keeping the knees straight. At the completion of maximal trunk flexion, the measurement of lumbar flexion was recorded by subtracting the initial distance from the final distance for each measurement. The results of this study found the interobserver reliability to be substantial (Pearson's r = 1.0) and verified the precision and objectivity of the measurement of spinal flexion using Schober's skin distraction technique.[12] The authors also concluded that the skin distraction method is inexpensive, quick, and easy to perform in a clinical setting.

Modified Schober Technique

Macrae and Wright[29] modified Schober's original method in 1969 and compared both of these methods to radiographs. The rationale behind this modification was that during anterior spinal flexion with the Schober's method, they observed both of the skin marks (the lumbosacral junction (L_5-S_1) and 10 centimeters above) to move superiorly relative to the spinous processes. Since the skin appeared to be well tethered and stretched from the coccygeal area, they suggested taking the measurement from a point lower on the sacrum. Therefore, the authors marked three areas in their study: the lumbosacral junction, five centimeters below, and 10 centimeters above as the Modifed Schober's technique. These measurements accounted for a total of 15 centimeters in the erect position. The investigators additionally studied the validity of this method by comparing the measurements of lumbar flexion obtained from Schober's and the Modified Schober's (MS) to radiographs. Lead markers were placed over the skin marks on 11 subjects with and without spinal disease, and radiographs were taken in the erect position and in full spinal flexion. The distraction of the markers was measured directly and the inclination of the lumbar spine was estimated by measuring the angle formed by lines connecting the anterosuperior corner of the first lumbar vertebrae, the sacral promontory, and a convenient bony landmark on the sacrum.[29] These same bony points were superimposed to each pair of films.

The results of this study confirmed a linear relationship between the distraction of the skin marks and true flexion of the lumbar spine with both methods. Pearson's correlation coefficients were $r = .90$ for Schober's and $r = .97$ for the Modified Schober. When checked radiographically, clinical identification of the lumbosacral junction was subject to an error of approximately two centimeters. To determine whether this interfered with test accuracy, the investigators marked the subjects in the usual manner and placed a second set of three marks either two centimeters above or below. The faulty landmarks were shown to seriously impair the accuracy of the Schober's method, but to rarely affect the modified method. For example, the authors stated that in the original method, placing the marks two centimeters too high caused an underestimate of up to 15 degrees, while placing the marks two centimeters too low resulted in an overestimate of up to 14 degrees as compared to radiographs. The errors were much smaller with the modified method, five degrees and three degrees respectively.

Furthermore, this study also found the MS method to be independent of hip movement. Radiographs were taken in both the erect and flexed positions of a subject with ankylosing spondylitis who presented with a "bamboo spine." Having normal hips, this subject was able to bend forward; however, there was no significant change in either the inclination of the spine or in the distance between the skin marks.[29] This study found the MS method to be a valid procedure correlating very closely (Pearson's r = .97) with anterior flexion measured radiographically. In addition, the authors concluded that this method of skin distraction is rapid, simple to perform, and does not cause any inconvenience for the subject.

Merritt and associates[9] investigated the intraexaminer and interexaminer reliability of the MS method described by McCrae and Wright.[29] The intraexaminer and interexaminer reproducibility of results was determined by calculating the coefficients of variation (CV) of the three examinations of each subject, and the mean and median CV over all individual CV's were calculated to summarize reproducibility over all subjects. The CV is a measure that is often used to describe the amount of variation in a sample and reflects all sources of variation, not just measurement error.[31] It is expressed as a percentage which is calculated by the formula: standard deviation/mean x 100. Because the CV is always a percentage, regardless of units of measurement analyzed, it is a useful statistic for comparing numerous types of measurements.[9] In addition, persons with high mean levels of a measurement often have greater variation in repeated determinations than do those with low mean values. The CV adjusts for these differences by expressing the variation relative to the mean.[9] Generally, the lower percentage reflects a good CV.

The results of this study of 50 healthy subjects demonstrated good reproducibility (CV = 6.3% for interexaminer reproducibility, and 6.6% for intraexaminer reproducibility). The authors suggested that the MS technique should be added to the routine examination of the back to improve objectivity. Similarly, in a study by Rae, Waddell, and Venner,[14] two of the authors independently assessed 30 patients for measurements of lumbar flexion using the MS method. In 80% of patients, the two observers agreed within 1.5 centimeters, and in 70% they agreed to within one centimeter. The authors concluded that this technique is easy to learn, simple to use, and takes only a few seconds to incorporate into a routine clinical examination. Likewise, they suggested that this tape measure and skin marking technique developed by Macrae and Wright[29] should become the standard clinical technique for measuring lumbar flexion. The reproducibility of this measurement technique is important to enable examiners to compare their results confidently with those obtained by other investigators who use the same techniques.

In contrast, a 1983 study by Portek et al[7] evaluated the MS method on 11 subjects between 25 to 36 years of age who had no history of back pain. The results of their study found this technique difficult to reproduce due to mobility of the skin over bony landmarks and to extensibility of the skin, resulting in the marks moving relative to each other during the attempts to measure the distance between them. Furthermore, the authors concluded that the distances measured with this technique were relatively small and that small deviations in skin markings appeared to produce large percentages in error.

In 1989, Mellin[32] studied the use of the MS method of 476 subjects with low back pain. The results of this study found this tape measurement of lumbar flexion to be significantly affected by weight and lordosis. The author concluded that the greater distention between measurement marks accompanying an increase in weight was probably caused by more subcutaneous fat in heavy subjects, thus causing inaccurate tape measurements of forward flexion. In addition, tape measurements of forward flexion were also found to have a positive correlation with lordosis. Therefore, it was concluded that both body mass index and lordosis decrease the reliability of tape measurements.

Biering-Sorenson[33] further evaluated the reliability of the MS method in a sample of 127 subjects. The results of this study found the MS to be reliable with a correlation variation of 4.8%, in contrast to an earlier study by Reynolds[19] which found a CV of 11.7%. Interestingly, this study[33] also examined hamstring extensibility and found no correlation between hamstring tightness and the MS method. The authors stated that this supports the earlier findings of Macrae and Wright[29] which found this method to be independent of hip movements.

Modified Modified Schober

In 1973, a study by Van Adrichem and Van der Korst[34] assessed the measurements of lumbar flexion using a tape measure in five men between 20 and 25 years of age. With the subject standing erect, skin markings were placed at the level of the posterior superior iliac spines (PSIS; S-2) and 5, 10, 15, and 20 centimeters superior. After the subject was in a maximally flexed position, the distances between the lowest mark and each of the four superior marks were measured. The results of this study indicated that the more superior the landmarks, the smaller the increase in length during lumbar flexion.[34] Therefore, the authors concluded that any landmarks between 15 and 20 centimeters above the midline joining the PSISs contributed little to the overall measure of lumbar flexion. They suggested that identification 15 centimeters above the level of the PSIS was a suitable landmark for measuring lumbar range of motion as the lumbar spine is approximately 15 centimeters in length. The authors described this measurement technique as the Modified Modified Schober (MMS).

In a recent study, Williams et al[31] determined the reliability of lumbar flexion using the MMS technique. This method was chosen for research by the authors due to the easily identifiable landmarks. Three physical therapists with clinical expertise in orthopedics took measurements of 15 subjects with low back pain. The therapists were given written instructions of the MMS technique and were allowed two practice sessions using the standardized protocols. All subjects were instructed to stand erect with their feet placed on footprints which were secured to the floor. A skin mark was placed in the midline of the spine connecting the PSISs and an additional mark was placed 15 centimeters superior. Each subject was then instructed to bend forward and measurements were recorded to the nearest one millimeter. All skin marks were removed with rubbing alcohol after each measurement. Reliability coefficient values were interpreted as described by Richman[35] where .80 to 1.00 is very reliable, .60 to .79 is moderately reliable, and .59 and below is of questionable reliability. The results of this study showed the MMS technique to have moderate reliability (ICC=.72). Therefore, the authors concluded the results of this study to be appropriate for future studies addressing the criterion-related validity of the MMS measurements.

In addition to determining the reliability of the MMS method, Williams et al[31] calculated the time taken to perform this technique by selecting a random sample of time in seconds for 10 different measurements performed by each therapist. This procedure was found to have a mean time of 10.2 seconds.

This supports earlier findings that the skin distraction method is a quick tool for the measurement of lumbar flexion in the clinical setting.

A potential drawback of using the measured distance of 10 centimeters as described by the MS method, or the 15 centimeter distance described by the MMS method, is the possibility of height and body dimension variations affecting the placement of a measured mark relative to the location of the first lumbar vertebrae.[31] For example, the length of the lumbar spine could vary significantly between persons of different stature. However, the study previously described by Van Adrichman and Van der Korst[34] found the upper lumbar levels to contribute minimally to the overall measurement of lumbar flexion. Therefore, Williams et al[31] concluded that height variations which could change the actual upper lumbar segments included in the 15 centimeter distance would have a minimal effect on the final measurement. The authors stated that the advantages of using a measured distance for identification of the superior landmark include minimization of error in the identification of the level of the first lumbar vertebrae, and the speed with which the measurements are taken. The authors concluded that these advantages outweigh any potential disadvantages.

There have been numerous studies on the measurements of lumbar flexion using the skin distraction techniques. Overall, the reliability found for all three methods is variable; however, most studies favor the Modified Schober technique developed by Macrae and Wright.[29] Their study was also significant in determining the criterion related validity of this method. Clinical ease of measurement with skin distraction methods have been suggested by most studies, and this was verified by Williams et al[31] which calculated a mean time of 10.2 seconds. These results are relevant in a clinical setting where there is a need for quick, reliable, and accurate measurements.

Fingertip to Floor

The fingertip to floor (FTF) method of spinal flexion differs from the tape measurement methods previously described as measurements are not taken directly over the lumbosacral area.[30] Instead, measurements of spinal flexion with this method are obtained by having the subject forward bend in an attempt to touch the floor with the fingertips. The distance between the tip of the third finger and the floor is then recorded using a tape measure. A recent survey of physical therapists revealed that the FTF method is still the most common technique used for measuring lumbar flexion.[36] The disadvantages with this method are that the measurements can be influenced by hip flexion, nerve root irritation, by psychological factors, and by flexion occurring at other spinal levels.[14] In addition, hamstring extensibility has been suggested by several authors to influence the FTF measurements. Mayer[17] stated that it is well known that an individual with a completely fused spine can bend completely forward in the presence of good hip motion alone. The advantages with tape measurements of forward flexion are that the subjects perform a pure and maximal movement which is conveniently measured.[33]

In 1986 Merritt et al[9] investigated the interexaminer and intraexaminer reproducibility of the FTF method with 50 normal subjects. In this study, the subjects were instructed to stand barefoot with the heels on the floor, feet shoulder width apart, and the knees straight. The subjects were asked to bend forward maximally as if to touch their toes and to maintain this position for 15 seconds. All subjects performed one instructional trial before the measurements were recorded. The distance from the tip of the middle finger to the floor was measured with a semi-rigid metal tape measure and was recorded to the nearest .50 centimeter. The results of this study found the mean CV's for reproducibility of results to be variable with the FTF method (intraexaminer CV, 76.4%; interexaminer CV, 83%). The authors concluded that the poor reproducibility of this method is attributable to the potential for hip flexion.

Gill et al[37] also found poor repeatability for the FTF method when they investigated 10 normal subjects. The subjects received the same instructions described above. The results of this study found the FTF method has a high variability in comparison to other techniques studied for repeatability of measurements of lumbar flexion. The authors did not describe the criteria used to differentiate between poor, fair, and good repeatability in this study. Although this test is used widely in the clinic, the poor intrarater repeatability was attributed to the influence of other vertebrae of the spine, and to the minor effects of flexion in the fingers, wrist, elbow, and shoulders. The authors also stated that the differences in mean variation in their study (CV 14%) and in the study previously described by Merritt[9] (CV 76%) could be due to the differences in time between trials.

In a 1983 study by Biering-Sorenson,[33] 449 men and 479 women of a suburb of Copenhagen, Denmark, participated in a general health survey which included a thorough physical examination relating to the lower back. The examination consisted of anthropometric measurements, flexibility/elasticity measurements of the back and hamstrings, and tests for trunk muscle strength and endurance. Hamstring extensibility and the FTF distance were measured on a subsample of 126 participants at the initial visit and at a follow up of six months. The positions and measurements of the FTF method were performed as described previously and the measurement was judged to the nearest whole centimeter. Hamstring length was assessed with two methods. Method I was with the straight leg raise (SLR) test, and method II was with the modified SLR test. Recordings for the SLR test was made in degrees, with any measurement less than 80 degrees representing tighter hamstrings. The modification of the SLR positioned the patient supine with the hip flexed to 90 degrees and the measurement of restricted knee extension was recorded. With this method, the higher degrees recorded represented tighter hamstrings.

This study found the FTF method to be reproducible even at an interval of six months. Altogether, there were 50 participants out of 126 who presented with two different values at the initial and six month follow up exam. Of these, 24 were lower and 26 were higher at the initial than at the six month follow up.

(24 vs 26: $x^2 = 0.80$, df = 1, p = 0.78). In addition, the FTF method correlated significantly with hamstring length (FTF: method I, Pearson's r = -.70 to -.73; FTF: method II, Pearson's r = .56 to .60). The authors stated that this correlation is not unexpected as the FTF distance depends on hamstring tightness.[33] The authors concluded that the FTF distance is a combined evaluation of at least hamstring tightness and spinal flexibility and, therefore, may be a misleading measurement.

A recent study by Newton and Waddell[36] examined the intertester reliability of the FTF method on 20 patients with low back pain. The subjects in this study were between 20-55 years which is the common age range for patients with low back pain.[36] The standardized position used in this study was as described in previous studies. The distances were also measured as described previously. The results were calculated using intra-class correlation coefficients to express the reliability of these measurements. The ICC = .98 found the FTF method to be reliable for measuring lumbar function. However, the authors postulated that it is not a valid method for measuring specific lumbar motion because it is considered a combined measure of lumbar flexion, hip flexion, and hamstring extensibility. However, the FTF method is a quick, easy, and reliable measure of improvement in function.

Modified Fingertip to Floor

A 1982 study by Frost et al[10] examined measurements of forward bending obtained using a modified version of the FTF method. The modified fingertip to floor (MFTF) method measures the distance of forward bending while the subject stands on a stool. The stool is included with this method to allow measurements of those subjects who are able to reach the level of the floor or beyond.

For this study, three physical therapists ranging in clinical experience from 1.5 to 6.5 years measured 24 subjects with a mean age of 33.8 years. All subjects were instructed in stretching exercises prior to the measurement session. The raters followed standardized instructions for the initial postures, verbal instructions, and landmarks used for the placement of the tape measure. These instructions consisted of the subjects standing on a 20 centimeter high stool with their heels together, knees straight, and arms in neutral. The subjects were then instructed to bend forward as far as they could while keeping the knees straight. The distance was measured from the tip of the right third finger to the top of the stepstool. Measurements below the level of the stool were negative, while those values above the stool were positive.

Reliability coefficients for rater, day, and repetition were calculated using the formula outlined in Winer[38] where rater x day x repetition is the reliability when these three components vary. The authors chose this method because this reliability corresponds to the clinical situation of when one therapist records measurements on one day, and another therapist records measurements on another day.[38] This comparison was referred to as a single measurement in this study. For the purposes of this study, the authors chose reliability coefficients greater than r = .80 as good, and those less than r = .80 to be poor. The results found a high measurement reliability (.82) for the MFTF method showing good reliability across raters, days, and successive repetitions.

A 1990 study by Gauvin, Riddle, and Rothstein[30] examined the intertherapist and intratherapist reliability of the MFTF method. In this investigation, randomly paired physical therapists took repeated MFTF measurements of 73 subjects with low back pain. Prior to the study, the investigators were instructed in the use of the tape measure and of the stool. However, specific instructions were not given on how to position the subjects, or how to instruct them in bending forward. All subjects stood on a 32.4 centimeter high stool and were instructed to bend forward. The distance was measured between the tip of the subject's middle finger and the top of the stool and was recorded to the nearest .10 centimeter. The measurement distances above the stool were positive, those below the stool were assigned negative values, and a zero was recorded if the patient was able to reach to the top of the stool. The results of this study reported that measurements of forward bending obtained on patients with low back pain using the MFTF method are highly reliable (intertester ICC = .95; intratester ICC = .98). In addition, this study reported that standardized instructions in patient positioning are not required for MFTF measurements to be highly reliable. Most importantly, this study indicated superiority of the MFTF method over the FTF method as 27% of the subjects were able to reach the level of the floor or beyond. The authors concluded that the construct validity of this method can be questioned as this distance includes motions in other joints which can affect the measurements obtained. In conclusion, the authors stated that measurements with the MFTF method are quickly and easily obtained and the reliability is unaffected by an increase in pain during forward bending.

Although the FTF method is the measurement technique most commonly used in the clinic, it is considered neither valid nor reliable for determining specific lumbar function. In addition, differences in arm and leg length among individuals may make this method inappropriate for making comparisons among subjects.[39] Even though the reliability of the MFTF method looks promising, the criterion related validity is questionable which warrants further studies. However, although the FTF methods are not a good measure of specific lumbar mobility, they should not be overlooked as a simple and reliable clinical method of showing changes in the amount of total motion in an individual over time.[36,39]

CHAPTER IV

GONIOMETERS

Goniometers are instruments commonly used by physical therapists for measuring joint motion. Various studies[15,40] have shown that measurement reliability of the goniometer varies according to the joint being measured, and intraobserver error has been notably less than interobserver error. However, these studies have generally been restricted to the measurement of the upper and lower extremities. The American Academy of Orthopedic Surgeons booklet suggests that where bony landmarks are not easily identifiable, estimating the angle is as good as, if not better than, using a goniometer.[27] As no evidence was offered to support this statement, Low[15] conducted a study in which 50 colleagues estimated and then measured elbow flexion and wrist extension with a goniometer. Only one measurement was allowed and no instructions were given to the observers. In the results of this study, Low found that measurement with a typical goniometer is more reliable than estimating motion purely by eyesight. In addition, the author concluded that using the average of several measurements obtained with the goniometer increases the reliability.

A study by Fitzgerald et al[12] suggested that goniometry is a relatively quick and easy alternative method for the measurement of spinal mobility.

Because the goniometer is the most commonly used instrument for measuring range of motion, the authors chose to assess the interobserver reliability of goniometric measurements obtained for right and left thoracolumbar flexion and for spinal extension. Anterior spinal flexion was measured by Schober's method as the authors found it to be a good clinical assessment technique. (These results were discussed in a previous chapter.) The interobserver reliability taken by two independent raters on 17 physical therapy students was significant with Pearson coefficients of $r = .76$ for right lateral flexion, $r = .91$ for left lateral flexion, and $r = .88$ for spinal extension.

In a 1985 study by Burdett, Brown, and Fall,[39] two physical therapists assessed the interobserver reliability of the standard goniometer for the measurement of lumbar flexion on 23 subjects between 20 and 40 years of age. In this study, the authors used a standard goniometer adapted with lines drawn on the goniometer arms which were perpendicular to the axes of the arms. The goniometer was used to measure the angle between wooden pointers mounted perpendicularly to the spine at the sacrum and at the thoracolumbar junction (T_{12}/L_1). One 1.5 x 2.5 centimeter rectangular plastic platform with a 10 centimeter wooden pointer was centered over the thoracolumbar junction and one was centered between the level of the PSIS (S_2) and a skin mark three centimeters below. The angle between the pointers was measured using the goniometer described above by aligning the pointers with the lines on the goniometer arms.[39] Subjects were measured positioned on an adjustable height chair with the thighs parallel to the floor, knees in 90 degrees of flexion, and with the ankles in neutral. Each subject was instructed to bend the trunk forward until the shoulders contacted the thighs, or to the maximum amount of flexion. The observers then instructed each subject to place the forearms under the thighs and to grasp the opposite elbows with the hands to stabilize the position, and the angle between the pointers was measured.

The measurement of lumbar curvature during trunk flexion was shown to be reliable with Pearson's $r = .85$. The authors stated that although the platforms and pointers can be applied easily to the back with double sided tape, the main problem with the reliability of this method is skin motion. For example, subjects with large skin folds under the platforms may cause the platforms to tilt resulting in inaccurate measurements. The authors concluded that this method is very versatile, especially when combined with photography. However, they suggested that further studies are needed as other methods may exist that are more reliable and valid for measuring regional spinal curvature.

There appears to be a paucity of studies which investigated the validity of the goniometric technique. The main disadvantage with the use of the goniometer for the measurement of spinal flexion is that lumbar motion is not measured separately from total spinal motion.[39] With the standard goniometer, restricting the measurement to the lumbar region is difficult, and pelvic tilt must be controlled closely or it will be included in the measurement.[39] According to

Mayer,[41] the universal goniometer is unsuitable for the measurement of lumbar spinal range of motion because the multiaxial movement of several joints is represented as uniaxial movement. An adaptation of the standard goniometer designed to separate the components of compound motions of the hip and spine in order to provide a more valid and reliable measurement includes the pendulum goniometer, or inclinometer, originally described by Loebl in 1967.[6]

CHAPTER V

INCLINOMETERS

An inclinometer is a hand held, circular, fluid-filled disc with a weighted gravity pendulum indicator that remains oriented in the vertical direction.[6,31] The disc is graduated in 0.5 degree intervals over the 360 degree range and is affixed either to a straight edge base, to a two-point contact base, or to a plastic goniometer. A two-point contact base is generally preferred as it maintains good contact over the convex dorsal aspect of the sacrum.[17] The use of the inclinometer for measuring back movement was described by Loebl in 1967.[6] On the basis of the assumption that the curvature of a spinal segment can be determined by the angle formed by the tangent of one point on the curve with the tangent of another point on the curve, he described a method of measuring four spinal segments with the use of a commercially available engineer's inclinometer (pendular goniometer).[9] Since that time, several clinical inclinometers have become available; however, in a review of the measurements of spinal movements, Pearcy[42] states that those inclinometers purchased from building merchants which are used for aligning roofs are effective, accurate, easy to use, and generally about one fifth of the cost of clinical models.

Loebl's inclinometer consisted of a dial divided into degrees and fixed to two plastic buttons about nine centimeters apart. When the buttons are held against the spine, the weighted needle remains vertical and indicates the angle of spinal incline.[22] Motion can be measured across any segment by calculating the differences between angles measured while the back is in neutral, flexed, and extended positions because all angles are relative to the always vertical gravity pendulum.[9] The advantage of the inclinometer is that the components of hip and lumbar movement can be separated. In addition, the results are reported in degrees which may make assessing the range of motion function easier.[31]

Single Inclinometer Technique

To measure lumbar flexion with the inclinometer, the spinous processes of L_1 and S_1 are palpated and the overlying skin is marked. The subject stands erect and the inclinometer is held against the back over each of the two skin marks with the pointer vertical. The difference between the inclinometer values at L_1 and S_1 is first recorded in a neutral position.[42] The subject then sits on a chair, bends forward as far as possible, and the inclinometer readings are repeated over the two skin marks. These data yield the spinal inclines and curvatures in standing as well as the range of flexion in the spinal portions from a standing position.[6]

A 1985 study by Reynolds[19] assessed the inclinometer method described by Loebl on 30 subjects, 10 of whom suffered from an arthritic disorder. The inclinometer used in this study differed from that described by Loebl in that the distance between the feet of the instrument was five centimeters instead of nine. In addition, the landmarks chosen for measurement also differed from those previously described and were from C_7, a point 10 centimeters above the thoracolumbar junction, and over the sacrum. In this study, all measurements were taken with the subjects standing rather than in the sitting position described by Loebl. The results of this study found that the inclinometer produced acceptable inter-observer error with Pearsons r = .77. Intra-observer error was assessed by calculating CVs for each measurement and was also acceptable (CV= 7.18%). The authors stated that the presence of the scapulae and adjacent musculature often made positioning the feet of the goniometer on the upper thoracic spine difficult. However, they concluded that by measuring the angle between the tangents to the spine at different levels, the inclinometer gives the best estimate of the true angular deviation of the spine.[19] Therefore, they suggested that it would be an acceptable method for making comparisons between individuals.

A study by Mellin[43] using the Myrin inclinometer found similar results. In this reliability study, two physical therapists trained in the use of the inclinometer took measurements on 25 subjects with a mean age of 31.3 years. The results showed good reproducibility for intraobserver and interobserver reliability (Pearson's r = .86, r = . 97). The author concluded that in order for the measurements to be considered reliable, proper training is needed in the methods, manipulation of the instrument, and in the instructions given to the subjects.[43]

Portek et al[7] studied radiological and clinical techniques for measuring spinal flexion on 11 subjects with a mean age of 29.5 years. Ten measurements were taken by one observer on one subject for intraobserver reliability, and two observers took measurements of 14 patients for interobserver reliability. Skin marks were placed over the spinous processes of L_1 and S_1 and measurements were recorded in the standing and seated positions previously described. The results of this study found measurements of lumbar flexion taken with the inclinometer to be reproducible by different observers. However, the authors suggested that this technique must be carefully monitored when comparing measurements by more than one observer.

This study also compared the inclinometer with radiological methods. Biplanar radiographs were taken with the subjects standing and in a maximally flexed position and were analyzed by marking nine bony landmarks on each vertebrae. This study found little correlation between the inclinometer measurements compared to X-rays. Therefore, the authors concluded that the inclinometer only gives indices of back movement which does not reflect true intervertebral movement.[7]

Merritt et al[9] researched the interexaminer and intraexaminer reproducibility of inclinometer measurements on 25 subjects. In this study, the authors chose a bony landmark 15 centimeters above S_1 as the upper lumbar point due to the difficulty of consistent accurate identification of the spinous process of T_{12}. In addition, they also altered the inclinometer to read from 0-360 degrees with zero degrees calibrated as the point closest to the body. The results found the reproducibility to be consistently good for the Loebl flexion test (interexaminer CV 13.4%; intraexaminer CV 9.6%). The authors concluded that the inclinometer method described in this study has excellent reproducibility and is easy to learn. Although the Loebl test does require some time and training, they stated that the modifications made in this study may simplify and improve the reproducibility of this test.[9]

Because the repeatability of external methods depends on the accurate recognition of bony landmarks, Salisbury and Porter[44] compared vertebral levels identified by palpation to those identified by ultrasound. In this study, the spinous processes of the S_2, T_{12}, and L_4 vertebrae were located by palpation and the skin marked. These landmarks were compared with subsequent identification of the vertebrae by ultrasound. In the results of this study, the authors stated that a nonmedical examiner failed to accurately locate the correct spinous process only 3% of the time. Therefore, they concluded that significant error in external methods due to inaccurate surface marking is unlikely.

A recent study by Newton and Waddell[36] tested the reliability and validity of lumbar flexion using a hand-held computerized inclinometer. The model used in this study was the EDI-320 manufactured by Cybex Inc. (Ronkonkoma, New York). To assess intertester reliability, two examiners took measurements on 20 patients with low back pain who were between 20 to 55 years of age. The measurement of lumbar flexion was taken by the inclinometer and recordings were made at S_2, and T_{12}/L_1 with the subjects in a standing position. The subjects were then instructed to bend forward as far as possible and the two recordings were repeated. These four readings permitted simple calculation of lumbar flexion, pelvic flexion, and total combined flexion.[36]

To assess validity, 10 patients received X-rays as part of a routine clinical examination. The inclinometer measurements were taken in the erect and fully flexed positions, followed by X-rays with the subjects maintaining the position in full spinal flexion. For this study, X-rays were measured by drawing lines parallel to the upper vertebral endplates of S_1 and the lower vertebral endplates of T_{12}, dropping perpendicular lines from these, and measuring the angle of inclination at their intersection.[36] This study showed the inclinometer to be a valid (Pearson's $r = .76$) and reliable (ICC's .94-.98) method of measuring lumbar mobility, to be versatile and easy to use.

Double Inclinometer Technique

A study by Mayer et al[17] assessed the validity of the double inclinometer (DI) technique described by Loebl[6] and Troup,[45] and compared the single inclinometer technique with this method. To take measurements with the DI method, one inclinometer is placed over the sacrum, as described previously, while the subject stands in an erect position. The second inclinometer is placed over the spinous processes of T_{12}/L_1. Both inclinometers are held in place with the subject standing, and angular readings are recorded. The subject is then instructed to bend forward maximally, and the readings of the two inclinometers are taken. The upper inclinometer reading represents gross motion, while the sacral inclinometer measures the motion at the pelvis or hip. Readings were calculated as follows: Gross motion = flexion measurement - erect measurement on the upper inclinometer, Pelvic motion = flexion measurement - erect measurement on the lower inclinometer, and True lumbar motion = gross motion - pelvic motion.[17]

For the comparison of pelvic motion with the inclinometric methods, measurements were obtained on 13 normal subjects using the DI and the single inclinometer technique. In the measurement of pelvic motion with the single inclinometer, the examiner palpated the anterior and posterior portions of the iliac crest with the thumb and index finger bilaterally with the fingers positioned parallel to the floor. An assistant then placed a single straight edge inclinometer over T_{12}/L_1 in the erect position and held it there while the subject flexed forward. The gross motion was read directly after, and the inclinometer was then placed across the plane between the thumb and the finger to measure pelvic motion.[17] The comparison of the single inclinometer with the DI found no difference in results between the two techniques. With the DI technique, mean pelvic flexion measured 63 degrees (SD, 14.8 degrees) and with the single inclinometer the mean range was 63 degrees (SD, 15.1 degrees).

To assess the validity, radiographic measurements were compared with the inclinometer measurements on 12 subjects who had chronic lumbar pain. The x-rays and measurements were taken in standing and in full spinal flexion. The radiographs were analyzed by a radiologist, and true lumbar motion was measured by subtracting the results of the full flexion film from those taken in the neutral position. The inclinometer measurements showed no significant difference from radiographs. The authors concluded that measurements taken with both the single and DI are quick, easy to use, and can be expected to give measurements within 10% of those taken with radiography.

In a study by Keeley et al,[1] two physical therapists assessed the reliability of the DI technique on nine subjects with chronic low back pain, and 11 subjects without back pain. All subjects were instructed in five repetitions of warm-up exercises of fully flexing and extending the spine prior to measurement. The results of this study found high correlations (>.90) for lumbar flexion for both interobserver and intraobserver reliability using the DI technique. However, the authors stated that the two-point contact of the inclinometer tended to wobble over the convex orientation of the sacrum, and therefore recommended that careful attention be made to the placement of the inclinometer over this area.

A recent study by Williams et al[31] determined the reliability of lumbar flexion measurements obtained with the DI method on 15 subjects with low back pain. Three physical therapists were given written descriptions of the DI technique prior to measurement, and standardized methods were followed. In this study, the skin was marked in the midline of the spine horizontal to the PSIS (S2), and another mark was placed 15 centimeters superior. Both inclinometers were placed over the skin marks, calibrated to zero degrees, and the measurements were taken as described in previous studies. The results of this study found the DI technique to have questionable reliability for the measurement of lumbar flexion (ICC = .60). The authors suggested that the difference in reliability reported in this study as compared to those reported by Keeley[1] which found high reliability could be due to an order effect in which the patients were measured or to the different anatomical placement of the inclinometers. The authors also stated that the therapists in this study complained of difficulty securing the inclinometers on the subjects as they moved into flexion.

The time taken to obtain lumbar flexion with the DI technique was calculated by taking a random sample of the time in seconds for 10 different therapists for 10 different measurements of flexion. The mean time for the use of this technique was relatively quick at 23.1 seconds. The authors concluded that although the DI technique is a quick method for obtaining the measurement of lumbar flexion, it needs improvement. Although it shows promise, it may require more time, calculations, and training to master the technique.[31]

CHAPTER VI

FLEXICURVES

A draftsman's flexicurve, a device capable of molding to the shape of the back, is another instrument used for measuring spinal motion. This instrument bends in one plane only and maintains its shape in order to be transferred to paper. The flexicurve employs the same geometry as the inclinometer, in which angular measures are derived from the intersection of tangents to the curves at various points.[46]

Hart and Rose[20] suggested that many of the commonly used tools for measuring lumbar flexion fail to quantify the vertebral body positions or to generate an angular measurement similar to radiographs. Therefore, they examined the reliability and validity of the flexicurve (flexible ruler). In this study, the examiners used a flexible ruler of pliable metal encased in supple nonelastic plastic which was 61 centimeters long and 0.8 centimeters wide. The measurements of lumbar flexion were made by firmly contouring the ruler to the skin over the spinous processes of L_1 through S_2. These skin marks were transferred to the ruler with a pencil and the curve representing the shape of the back was transferred to poster board. Trigonometric calculations and formulas were then used to reduce the shape of the lumbar spine to an angle in degrees. The angle was considered positive if it was anterior (forward bending) and negative if it was posterior (backward bending).

To assess intratester reliability of the flexicurve, one author took measurements on six subjects in the positions of normal quiet standing, forward bending in a subject preferred manner, forward bending with a trunk curl, and forward bending while keeping the back straight. The 23 pairs of standing measurements and 66 pairs of complete forward bending measurements found the flexicurve to be a reliable tool for the quantification of the shape of the lumbar spine for test-retest reliability (ICC = .97).

The validity of the flexicurve was also assessed by comparing the measurements of the flexicurve to the radiological shape of the intervertebral segments. Each of the six subjects were measured with the flexicurve prior to a radiograph of the lumbar spine. To confirm the anatomical level of the skin markers, small metal markers were placed over the lumbar spinous processes. The center of each vertebral body was then located on the radiograph and connected in order to measure the shape of the back. The intervertebral segments between the points defined a curve on the radiograph similar to the arc of the shape of the back made by the flexicurve.[20]

The angle of the flexible ruler measurements (a) and the level confirmed roengenographic measurements (b) were compared to each other and to a traditional measure of sagittal plane vertebral body positions (c)[20]. For this measurement (c), lines were drawn tangentially to the anterior and posterior inferior lips of the roentographically confirmed vertebral bodies. The degree of association between the three measurements was then analyzed with the Pearson's Product Moment Correlation. A poor correlation was found between the flexible ruler measure (a) and the vertebral axis (b) ($r = .51$ $N = 8$). However, a good correlation was found between the flexible ruler measurement (a) and the vertebral angle (c) ($r = .87$, $N = 8$) and between the vertebral axis (b) and the vertebral angle (c) ($r = 0.79$, $N = 8$).

The authors[20] concluded that the flexicurve allows for the measurement of the spine without the influence of hip motion and may be compared directly to radiographs. In addition, the trigonometric calculations used in this study allow the flexicurve to be compared to other tools which measure motion in degrees. Finally, the authors suggested that clinicians may elect to utilize this tool without the time consuming calculations by simply comparing the shapes of the curves between treatments to determine changes in patients over time.

A 1985 study by Burton[21] assessed the reliability and validity of the flexicurve. The flexicurve used in this study was 350 millimeters in length and adapted to include two brass slides and a permanent mark 20 millimeters from the end of the curve. This investigation calculated regional sagittal mobility by reference to tangents to the curves at the spinous processes of T_{12}, L_4, and S_2.

Measurements of lumbar flexion were taken by a trained observer on 15 healthy subjects. Each subject was measured in a seated position and with the lumbar spine maximally flexed so that the upper trunk could pass between the knees. The spinous processes of T_{12}, L_4, and S_2 were identified with corresponding marks placed on the skin. With the subject in the position described, the examiner molded the flexicurve to the mid-line contour of the spine with the permanent ink mark of the flexicurve placed over S_2, and the brass slides adjusted to lie over the skin marks of L_4 and T_{12}. The flexicurve was then carefully removed from the subject's spine and the contour was drawn on a sheet of paper with marks locating the three spinous processes.

To measure the amount of lumbar flexion, tangents were drawn to the curves at the three spinous processes. The angles formed by the intersection of the tangents were measured with a protractor to give a measure of the sagittal movement occurring in the upper and lower lumbar regions from the tangent at L_4.[21] The intraobserver reliability of the flexicurve was good with CV = 8.75%. However, the authors suggested that this value may have been influenced by the use of an observer who was very familiar with this technique.

To assess the validity of the flexicurve, the authors compared the measurements to radiographs. Radiographs were taken with the flexicurve taped to the subject's lumbar spine with lead markers at T_{12} and S_2. Tangents were then drawn at these marks on the flexicurve trace and at the same spinous processes on a paper trace made from the radiographs. The results of this study found the flexicurve to be a valid measurement of lumbar flexion as recordings were within one degree of those measured from radiographs. The authors concluded that these results demonstrate the ability of the flexicurve to measure intervertebral motion. Furthermore, they stated that this method offers additional information due to its ability to characterize regional lumbar sagittal mobility.[20]

Salisbury and Porter[44] assessed the reliability of several instruments for measuring lumbar flexion in 1986. The results of their study found the flexicurve to correlate well with the goniometer (r = .94). Although the flexicurve is less expensive, the author favored the use of the goniometer due to its simplicity. The author stated that the drawing of flexicurve tangents introduces a secondary error, thus accounting for slightly poorer repeatability.

A similar study by Tillotson and Burton[46] evaluated the reliability and validity of the flexicurve and compared the measurements with the inclinometer. The results of this study found the flexicurve to provide a close approximation to radiographs (within 6 degrees) and to have a repeatability of three to four degrees. This study also assessed short term and long term variability between measurements and found that new skin marks and daily variation have little effect on the repeatability of this technique.

In addition, the data suggested that the flexicurve is less biased than the inclinometer. The lower values generated by the flexicurve were considered to be more accurate in view of the results of the radiographs.[46] The author stated that the higher values obtained with the inclinometer may have been due to the five centimeter distance between the feet which could have likely included an extra spinal segment and thus increased the angle recorded.

Although most studies have found good reliability and validity with the flexicurve, the major disadvantage appears to be with the calculation of the measurements. The drawing of tangents and measurements of angles of the curves is laborious and requires time in order to be accurate. However, software is available which allows tangents to be drawn using a computer-aided system which may reduce error. The results of these studies are significant for further research.

CHAPTER VII

CONCLUSION

In conclusion, there are many other special instruments for measuring lumbar flexion which are beyond the scope of this paper. This review has elucidated several of the techniques described for measuring flexion of the lumbar spine. These include tape measurements, contour measurements, goniometers, and inclinometers. Each of these techniques has inherent advantages and disadvantages related to their ease of administration, reliability, and validity (Table 1).

The results obtained with the goniometer and flexicurve are reported in degrees which makes impairment assessment easier, as it is typically based on degrees of movement.[37] In contrast, measurements obtained with tape measures can only be used to monitor progress of an individual subject and are not easily compared with other methods.

Goniometry and tape measurements from the fingertip to the floor appear to be the easiest to use, and although they show good reliability, their validity has not been established. Investigators conclude that these tools are not valid for measuring specific lumbar motion as the measurement is influenced by hamstring tightness, motion of the hips, and of corresponding spinal segments.

Table 1. Advantages and Disadvantages of Commonly Used Clinical Tools to Measure Lumbar Flexion

Instrument	Advantages	Disadvantages
Superimposition of radiographs	direct measure	cost, exposure to radiation, accessibility of equipment
Tape measure over spine	overall good reliability validity, inexpensive, quick, rules out hip motion	not measured in degrees, difficult to compare with other methods
Fingertip to Floor	quick and reliable for improvement in function	not valid for specific lumbar motion
Goniometer	inexpensive, quick, easy to use, good repeatability	not valid measure of lumbar motion
Inclinometer	rules out hip motion, fairly quick, good reliability and validity, reported in degrees	requires training in use, monitoring of instrument placement
Flexicurve	validity reflects intervertebral motion, regional sagittal mobility, reliable, reported in degrees	time consuming, requires drawing tangents, measurement of curves

However, the FTF techniques are suggested to provide reliable measures of overall improvement in function. Contour tape measurements which include modifications of Schober's technique are variable; however, most studies favor the Modified Schober's method. This technique has been found to be both valid and reliable, and to be both quick and easy to use in the clinical setting.

By measuring angles between tangents to the spine, numerous studies suggest inclinometers and flexicurves to give a valid estimate of true angular deviation of the spine. Both are inexpensive and are relatively simple to use, although several examiners reported difficulty with the placement of the inclinometer. This tool gives accurate measurements, but it requires training in use and careful monitoring in placement of the instrument. The advantages of the flexicurve are that its validity reflects intervertebral movement and that it has the ability to characterize regional sagittal mobility. However, the task of drawing tangents to the curve and the measurement of the angles can be both tedious and time consuming. The computer-aided system available could offer an improvement.

The complexity of the structure of the back and spine is such that the measurement of its motion should also be expected to be difficult.[41] It is essential to have a measurement tool in the clinical setting which is reproducible, accurate, and takes only a short time to perform. Although there are several inexpensive tools available which measure lumbar flexion reliably, it appears that a true gold standard has yet to be described.[47]

The intention of this literature review was to present the reader with a resource of those techniques commonly used for measuring lumbar flexion. Many methods have been described which will allow the reader to weigh the advantages and disadvantages of each when using them in the clinical setting. More importantly, it is hoped that the information presented in this review will stimulate further research to allow for greater accuracy in the measurement of flexion of the lumbar spine.

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