THE RELATIONSHIP OF THE SIT AND REACH TEST TO CRITERION MEASURES OF HAMSTRING AND BACK FLEXIBILITY IN ADULT MALES AND FEMALES

THESIS

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Nancy Jane Langford, B.S.
Denton, Texas
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The purpose of this study was to examine the criterion-related validity of the sit and reach test as a measure of hamstring and low back flexibility in adult males and females.

Subjects were 52 males and 52 females, 20 to 45 years of age. Hamstring flexibility was measured using a goniometer. Spinal flexibility was measured using a tape measure and an inclinometer. The sit and reach test was performed according to the AAHPERD Health Related Fitness Test Manual. Data were analyzed using correlations and appropriate descriptive statistics.

Conclusions of the investigation were: 1) in adult males 20 to 45, the sit and reach test is a valid measure of hamstring flexibility but has questionable validity as a measure of low back flexibility, 2) in adult females 20 to 45, the sit and reach test is a moderately valid measure of hamstring flexibility and is not a valid measure of low back flexibility.

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CHAPTER I

INTRODUCTION

Throughout the years, research has documented the lack of muscular fitness of the American youth (Kraus & Hirschland, 1954). As time passed, physical education programs were developed to overcome and correct this situation by emphasizing speed, power, agility, cardiorespiratory endurance, and muscular strength and endurance (Pate, 1983). By 1980, a new test of health-related physical fitness was developed which measured cardiovascular endurance, body composition, flexibility, and muscular strength and endurance (Pate, 1983), demonstrating the 1970's trend of physical fitness. Health-related physical fitness includes components of fitness which are related to the therapeutic values of exercise (Pate, 1983). This new perspective led to a revision of an earlier test by the American Alliance of Health, Physical Education, Recreation, and Dance, which in 1980 resulted in the AAHPERD Health Related Fitness Test (Jackson & Baker, 1986).

Chronic low back pain is the number one cause of disability below the age of 45, and the third major cause over the age of 45 (Mayer, Gatchel, Kishino, Keeley, Capra, Mayer, Barnett, & Mooney, 1985). Back pain is associated with decreased flexibility of the lumbar spine. Low back pain patients demonstrate less gross spinal flexion than those without pain (Mayer, 1984). Data suggest many health problems such as back pain are chronic and progressive beginning in childhood and reaching clinical levels in the middle of late adulthood (Pate, 1983). The battery in the AAHPERD Health Related Fitness Test included the sit and reach test to measure low back flexibility. However, a recent report suggests the sit and reach is not a valid assessment of either total back or lumbar flexibility in young females but was moderately related to hamstring flexibility (Jackson & Baker, 1986). This is important since hamstring tension is a major limiting factor in lumbar flexion (Mayer, 1985).

Purpose of the Study

The purpose of the present investigation was to examine the criterion-related validity of the sit and reach test as a measure of hamstring and low back flexibility in adult males and females. This was accomplished by determining the relationships between the sit and reach test and criterion measures of hamstring and back flexibility.

Significance of the Study

This study is significant to the exercise physiologist, the physical education teacher, and the physical therapist. The sit and reach test is a widely used field test of low back flexibility. Validity information is needed for appropriate applications in the field.

Delimitations

The results of this study have been delimited to adult males and females between the ages of 20 to 45 years.

Limitation

The findings have been limited to the accuracy of the measurements gathered.

Definition of Terms

Flexibility. Range of motion about a joint.

Total back flexibility. Maximal forward flexion of the spine as measured from the seventh cervical vertebra.

Thoracolumbar flexibility. Maximal forward flexion of the spine as measured from the thoracolumbar junction.

Pelvic flexibility. Maximal forward flexion of the spine as measured at the sacrum.

Lumbar flexibility. Mathematically computed total of thoracolumbar less pelvic flexibility, representing maximal lumbar flexion.

Hamstring flexibility. Maximal range of motion of hamstring musculature.

<u>Goniometer</u>. Protractor-like instrument to measure joint motion, having two arms which intersect in a 360-degree dial.

<u>Inclinometer</u>. Variation of the goniometer, also used to measure joint motion, consisting of a circular fluid-filled disc with a weighted gravity pendulum indicator that remains oriented in the vertical direction.

CHAPTER REFERENCES

American Academy of Orthopaedic Surgeons. (1965). Joint motion; method of measuring and recording. Chicago: American Academy of Orthopaedic Surgeons.

Jackson, A. W., & Baker, A. A. (1986). The relationship of the sit and reach test to criterion measures of hamstring and back flexibility in young females. Research Quarterly for Exercise and Sport, 57, 183-186.

Kendall, F. P. (1965). A criticism of current tests and exercises for physical fitness. Journal of the American Physical Therapy Association, 45(3), 187-197.

Kraus, H., & Hirschland, R. P. (1950). Minimum muscular fitness tests in school children. The Research Quarterly, 21, 25-33.

Mayer, T. G. (1985). Using physical measurements to assess low back pain. The Journal of Musculoskeletal Medicine, 2(6), 44-59.

Mayer, T. G., Gatchel, R. J., Kishino, N., Keeley, J., Capra, P., Mayer, H., Barnett, J., & Mooney, V. (1985). Objective assessment of spine function following industrial injury. A prospective study with comparison group and one-year follow-up. Spine, 10(6), 482-493.

Mayer, T. G., Tencer, A. F., Kristoferson, S., & Mooney, V. (1984). Noninvasive techniques for quantification of spinal range-of-motion in normal subjects and chronic low-back dysfunction patients. Spine, 9(6), 588-595.

Pate, R. R. (1983). A new definition of youth fitness. The Physician and Sports Medicine, 11(4), 77-83.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this literature review is to examine past research into the areas of warm-up, flexibility as related to anthropometric measurement, sit and reach test, hamstring flexibility, goniometric measurement, MacRae and Wright test protocol, and inclinometer measurement.

Warm-up. Fieldman (1968) studied the effect of warm-up exercise on flexibility of the hip joint. Realizing the controversy regarding the value of warm-up, Fieldman selected 33 college students enrolled in physical education courses, and collected data as each performed the toe-touch test. Fieldman's purpose was to assess the contribution of hip flexibility on the toe-touch test after performing selected flexibility exercises as warm-up. Six tests were performed over a five week period. The first and sixth tests were done without warm-up exercise. The second through fifth tests had varying degrees of warm-up exercises. Tests were performed early in the morning on a specified day, one test trial per subject. Results of the study indicate that the warm-up exercises were a definite aid to increasing range of motion in hip flexibility. Differentiation between the contribution of lumbar extensor and hamstring musculature was not discussed.

The above article reviewed the effects of warm-up exercises on flexibility. Although no differentiation was made to determine where the increased flexibility occurred, the research was conclusive that warm-up exercise increased flexibility at the hip.

Relationship between flexibility and anthropometric measurements. Seven research studies evaluated the relationship of hip flexibility and anthropometric measurements. Mathews, Shaw, and Bohnen (1957) were interested in relationship of body segment, particularly leg length, to ability to touch the floor from standing position. The investigators collected data on 66 college women enrolled in physical education classes as each performed the Adapted Kraus-Weber Floor Touch Test, the Leighton Flexometer Test, and the Wells Sit and Reach Test. Anthropometric data on each woman included the distance from the greater trochanter to the floor, standing vertical reach, and standing height. Mathews, Shaw, and Bohnen concluded there was no significant relationship between the three tests of flexibility to the length of selected body parts.

Broer and Galles (1958) designed their study to determine the importance of the relationship of trunk-plus-arm length (reach) to leg length in the ability to perform the toe-touch test. Broer and Galles collected data on 100 college women enrolled in physical education classes. Flexibility tests of the back and hip were measured by the toe-touch test and the

Leighton Flexometer. Anthropometric measurements consisted of standing height, standing reaching height, and leg length. Results of the research were two-fold. For those persons with average body builds the relationship of trunk-plus-arm length (reach) to leg length was not a significant factor in the performance of the toe-touch test. For those persons with extreme body types however, the relationship of trunk-plus-arm length (reach) to leg length was significant in the performance of the toe-touch test. Those individuals with longer trunk-plus-arm length (reach) measurement and relatively short legs demonstrated an advantage in the performance of the toe-touch test. Those, however, with a relatively short trunk-plus-arm length (reach) measurement and long legs have a disadvantage in performance of the toe-touch test.

Mathews and Shaw combined again to study hip flexibility, this time with Woods (Mathews, Shaw, & Woods, 1959). The purpose of this study was to determine the relationship among two tests of flexibility, the Wells Sit and Reach test and the Adapted Kraus-Weber Floor Touch Test, in the anteroposterior plane and selected anthropometric measures, this time among elementary school aged boys. The anthropometric measures included the standing reach, standing height, and distance from the greater trochanter to the floor. One hundred and fifty-eight males were tested. Mathews, Shaw, and Woods summarized that no significant relationship was found between the three anthropometric measures when correlated against the two flexibility tests. Correlations between body length measures and flexibility were statistically insignificant.

Wear (1963), in investigating the relationship between measures of trunk and hip flexibility and lengths of certain body segments involved in the flexibility measures, concluded the sit and reach test was not significantly related to leg length; however, as did Broer and Galles (1958), he concluded that sit and reach flexibility was significantly related to excess of trunk and arm length over leg length. Wear collected data from 116 college men performing the Wells and Dillon Sit and Reach Flexibility Test. Anthropometric measures of leg length, standing reach length and upper body length were taken. Trunk and arm lengths were mathematically determined from standing reach length.

Laubach and McConville participated in two research studies published in 1965. The purpose of Laubach and McConville (1965a) was to examine the relationship between flexibility and anthropometric measurements, anthropometric measurement and somatotypes, and flexibility and somatotypes. Sixty-three college men participated in 14 flexibility measurements evaluated with a Leighton flexometer. Forty-six anthropometric measurements as well as an additional 17 computed measures were used in the analysis. The Sheldon somatotype assessment was included.

Laubach and McConville concluded that the correlation between flexibility and anthropometric measurements were low and mostly insignificant and that there was a general lack of relationship between flexibility and somatotype.

Laubach and McConville (1965b) later proposed a study to investigate the relationship between muscle strength, flexibility, anthropometric measurements, and somatotype compoments. Forty-five male subjects aged 17 to 35 years participated in 4 measures of muscle strength, trunk flexion/extension and hip flexion/extension measured with a Leighton flexometer, 23 direct anthropometric measurements, seven additional computed measures and the Sheldon somatotype assessment. From this research Laubach and McConville concluded that the correlation between flexibility and anthropometric measures was statistically insignificant and a general lack of relationship existed between flexibility and somatotype.

Harvey and Scott (1967) tested the reliability of the bend and reach test as a measure of spinal forward flexibility as related to selected body measurements. One hundred college women were tested on the bend and reach flexibility test. Anthropometric measures included height, leg length, arm length, and trunk length. Results demonstrated no significant relationship between the length of the body segments or leg over trunk ratio and the best scores obtained on the bend and reach test.

The conclusion drawn from the research above shows no significant correlation between anthropometric measurements and flexibility. Two studies demonstrated some relationship between excess trunk plus arm length over leg length; these scores, however, were countered by individuals with short trunk plus arm length in normative data.

Testing Devices

Sit and reach. Prior to 1952 the "Standing, Bobbing" test described by Scott and French (1950) was used to determine back and hamstring flexibility. Each subject stood on a bench, flexed forward, bounced four times, and held the fourth reach at a position of maximum flexion. The measure was determined by a vertical scale from the floor.

Wells and Dillon (1952) determined the "Standing, Bobbing" test gave participants a feeling of insecurity which prevented a maximum effort from being obtained. Wells and Dillon thus created the Sit and Reach Test. One hundred college-age physical education students participated in the research study. Each subject did warm-up exercises for three minutes, then performed tests of back and leg flexibility eight times. Results of the research revealed the Sit and Reach test as a valid test of back and leg flexibility. Compared to a validity of 0.90 measured by the "Standing, Bobbing" test, the sit and reach was determined to have a reliability coefficient of 0.98.

A summary of reliability coefficients by other previously discussed researchers is presented in Table I. Reliability coefficients of the floor touch test (Bend and Reach or Adapted Kraus-Weber) are presented in Table II. Data presented in Tables I and II indicate the sit and reach/bend and reach/floor touch test, all similar in procedure, represent reliable instruments.

TABLE I

TEST-RETEST RELIABILITY OF THE SIT AND REACH TEST

	Subjects				
Author(s)	Date	Age	Sex	N	Test-Retest Reliability
Wells & Dillon	1952	college	F	100	0.98
Mathews et al.	1957	college	F	66	0.87
Mathews et al.	1959	3-6 grade	M	158	0.84
Wear	1963	19-24 yrs	M	62	0.94
Jackson & Baker	1986	13-15 yrs	F	100	0.99

TABLE II

TEST-RETEST RELIABILITY OF THE FLOOR TOUCH TEST

Author(s)	Subjects				
	Date	Age	Sex	N	Test-Retest Reliability
Poley	1948	college	F	63	0.93
Phillips et al.	1955	elementary	M/F	215	0.95
Buxton et al.	1957	1-8 grade	M/F	...	0.95
Magnusson	1957	1st grade	M/F	...	0.70
Magnusson	1957	6th grade	M/F	...	0.84
Mathews et al.	1957	college	F	66	0.98
Broer and Galles	1958	college	F	50	0.97
Mathews et al.	1958	3-5 grade	M	158	0.89
Harvey and Scott	1967	college	F	100	0.86-0.98
Frost et al.	1982	adult	M/F	24	0.82
Jackson & Baker	1986	13-15	F	100	0.97-0.98

The sit and reach test apparatus used in the current research study was a 12 inch by 12 inch wooden box constructed in accordance with the directions in the AAHPERD Health Related Fitness Test Manual (AAHPERD, 1980). The box was assembled with nails and wood glue. A tape measure with centimeter gradations was attached to the top panel with the 23 centimeter mark exactly in line with the foot board, the vertical plane against which the subjects feet were placed. The scale extended from zero to 50 centimeters.

Test-retest reliabilities of the sit and reach and floor touch tests were stastically significant. Since 1952 the Sit and Reach test has been used as a reliable tool for measuring back and leg flexibility.

Goniometric measure. In order to determine hamstring flexibility independent of low back musculature, the straight leg test was performed using a goniometer for measuring the joint angle. The supine straight leg raise stretches the hamstring muscle to its maximal extensibility (Mayer, 1985). The goniometer is a protractor-like apparatus with two arms extending from a 360 degree dial and is named for "goniometry," the measurement of joint motion. The goniometer is a primary measurement tool in physical therapy for initial assessment and determining patient progress. The goniometer produces objective, valid, and reliable data (Hellebrandt, Duvall, & Moore, 1949; Boone, Azen, Lin, Spence, Baron, & Lee, 1978; Low, 1976). Placement of the goniometer is centered around the joint to be tested. The axis of the 360-degree dial is placed appropriately next to the corresponding joint, one arm is placed parallel to the neutral position, and the other follows the movement of the limb tested. Accuracy of goniometric measurement is based on expertise of the tester. Placement of the goniometer is precise and has been well documented in several articles and books (American Association of Orthopaedic Surgeons, 1965; Cole, 1971; Hoppenfeld, 1976).

Moore (1949a, 1949b) reviewed many tools for recording measurements of range of motion, and argues that, whatever method selected for use, all measurements made in any one setting should be done with one type of instrument.

Hellebrandt et al. (1949) concluded the mean error for an average trained physical therapist was 4.75 degrees. He found experienced physical therapists averaged 3.76 degrees for mean error, and physicians noted a 5 degree mean error.

In determining normal range of motion in male subjects, Boone and Azen (1979) studied 109 males aged 18 months to 54 years, using a goniometer as the measurement tool. The authors concluded that one tester should be used for repetitive clinical measurements, particularly for any given population or in a longitudinal study.

Boone et al. (1978) studied the reliability of goniometric measurements prior to the study mentioned above. The purpose of the study was to determine inter- and intratester variability and the difference in test reliability of the measurements of each motion. Twelve males 26 to 54 years of age were tested in 6 motions. Each motion measurement was repeated three times by each of 4 testers at each measurement session. Results of this research showed intratester reliability for upper extremity motions equaled 0.89 and for lower extremity motions equaled 0.80.

Mitchell, Miller, and Sturrock (1975) evaluated the goniometer as an objective parameter for measuring joint motion. By testing 15 females and 5 males, ages not reported, each of 2 observers measured passive knee flexion and extension. Interobserver correlation was 0.956. Intra-observer testing also demonstrated little variation. The researchers stated observer error must be quantified for each tester taking a series of measurements, in order that objective assessment of the result of treatment can be made.

Rothstein, Miller, and Roettger (1983) also researched goniometer reliability but in the clinical setting. Intra- and intertester reliability were two of the four purposes studied in regard to measurement with a goniometer. Twenty-four patients were measured for each motion of elbow and knee flexion and extension. Intra-tester reliability ranged from 0.91 to 0.99. Intertester reliability ranged from 0.83 to 0.97 except for measurement of knee extension for which the correlation was found to be 0.57 to 0.68. Rothstein et al. further noted the results of goniometric measurements were reliable with taking only a single measure.

Table III reveals data demonstrating the reliability of the test-retest of the hamstring stretch. The straight leg raise allows for maximal stretch of the two-joint hamstring muscle.

TABLE III

TEST-RETEST RELIABILITY OF
HAMSTRING FLEXIBILITY

Author(s)	Date	Subjects			Test Re-Test Reliability
		Age	Sex	N	
Troup et al.	1968	18-28	M/F	13/11	L 0.85 R 0.84
Ekstrand et al.	1982	20-30	M	22	...
Bohannon	1982	20-32	M/F	2/9	0.99
Jackson & Baker	1986	13-15	F	100	0.99

Table IV concludes the reliability of joint motion measurements. Both the goniometer and flexometer demonstrate high correlation for test-retest reliability.

TABLE IV

TEST RE-TEST RELIABILITY OF
JOINT FLEXIBILITY

		Subjects			
Author(s)	Date	Age	Sex	N	Test-Retest Reliability
Leighton**	1955	16	M	120	0.913-0.996
Troup et al.*	1968	18-28	M/F	13/11	0.84-0.85
Mitchell et al.*	1975	...	M/F	5/15	0.956
Boone et al.*	1978	24-54	M	12	0.80-0.89
Rothstein et al.*	1983	...	...	24	0.91-0.99
Jackson & Baker**	1986	13-15	F	100	0.99

*goniometer test **flexometer test

The goniometer has been used as a reliable tool in measuring joint motion. Physical therapists have used the instrument as a primary measure of objectivity. It is conclusive that experienced testers are the most reliable in using this tool. All testers in any one facility should use the same instrument for measurement.

Distraction method for spinal motion evaluation. Tests for spinal mobility should be rapid and simple to perform with the least inconvenience to the subject, as well as providing an accurate assessment of range of motion. Methods have evolved over the years to overcome difficulties of spinal range of motion measurements and have been used to make a closer study of the functional relationship between lumbar spine and hip movement (Troup, Hood, and Chapman, 1968).

Noting the distances between spinous processes diminish upon extension of the spine, McKendrick (1916) proposed to measure lumbar movement by comparing interspinous distances in flexed and extended postures. This method has become customary clinical practice (Troup et al., 1968).

Schober (1937) described a simple test of anterior flexion which depended upon the distraction of skin over the back when eliciting a flexion motion. In this research study, Schober had each subject stand erect while the lumbosacral junction was identified and marked. A second mark was placed 10 centimeters above the lumbosacral junction. The distance between the two marks was measured as the patient flexed forward as far as possible. The increase in measure equaled the anterior flexion (MacRae & Wright, 1969).

Israel (1959) studied a technique using a flexible ruler to reproduce spinal contour. This method was not easily reproducible due to difficulty aligning the ruler accurately to the spine and due to errors in reproducing curves of known radius (Troup et al., 1968). In this method bony landmarks were identified and tangents drawn. Israel measured the angles of intersection of the tangents in two postures and estimated the movement between them.

Flint (1963) provided a suitable method for gross movements of the spine in which markers were placed at midline perpendicular to the contour of the spine and then correlated lumbar posture measurements obtained from photographs of the markers with radiographic measurements. Correlations were not made at the same time (Troup et al, 1968).

Troup et al. (1968) measured 10 female and 10 male students and technical staff members aged 18 to 26. A photographic study of lumbar vertebral posture was made of each subject in different body positions using external markers. The purpose was to investigate the effect of posture of the lower extremities on the lumbar spine. Results proved coefficient of correlation 0.91 between erect and fully flexed postures upon taking photos, enlarging them and measuring angles with a rotating protractor scale. Troup et al. further measured maximal lumbar range of motion, hip range of motion, and straight leg raising to study relationships between them. In this part of the study, 230 male and female young adults were measured in the motions mentioned previously. The method of spine flexion/extension was based on Lindahl (1966). Lumbar motion was calculated from the difference between the ranges of hip flexion and extension at the hip joint and of the hip and lumbar spine combined. The second measure was made by measuring the angle between the femora and a tangent to the spine at T11/12 in a fully flexed position. Troup et al. concluded this method of measuring lumbar sagittal mobility to be too complex for clinical use. Too many individual measurements were necessary in addition to lack of subject comfort. Sacroiliac movement also caused error.

Inspired by the test of anterior flexion described by Schober (1937), MacRae and Wright (1969) modified the procedure by including a third mark placed 5 centimeters below the mark at the lumbosacral junction (the second mark had been placed 10 centimeters above the lumbosacral junction). MacRae and Wright tested 195 females and 147 males. The erect distance between the lumbosacral junction and a mark 10 centimeters cephalic and the distance between the 10 centimeter mark and that 5 centimeters below the lumbosacral junction were measured and again at extreme spinal flexion. The accuracy of this test was checked by taking lateral radiographs of the subject erect and flexed with lead markers over the skin marks. The results of the study show this objective measure of anterior flexion of the lumbar spine is accurate and reliable. The 15 centimeter spread produced sufficiently more accurate data than the 10 centimeter spread. Furthermore, the test showed anterior flexion of the lumbar spine to be a graded character which is sex and age dependent.

Moll and Wright (1971) studied 119 males and 118 females between the ages of 20 and 90 years using the anterior flexion measure described by MacRae and Wright (1969) as described above to determine a range of normal values for spinal mobility. Reynolds (1975) also followed Moll and Wright in his study to compare three methods of spinal mobility measurement: the spondylometer, skin distraction, and inclinometer. Reynolds felt the skin distraction test to be least satisfactory of the three regarding reproducibility of results, correlation with other techniques, and convenience for the subject and researcher.

Adrichem and Korst (1973) also chose the tape measure of skin distraction as the method to evaluate 109 girls and 149 boys ages 6 to 18 years to assess flexibility of the lumbar spine. Five spinal locations were marked on each subject, the lumbosacral junction and 5, 10, 15, and 20 centimeters cephalically from the lumbosacral junction. The measured marks were located with a steel tape measure, while the lumbosacral junction was located by the intersection of a line joining the dimples of Venus and the spine. Measurements were made as the subject flexed to his maximum forward position between the lumbosacral junction and each of the four other marks. Measurements were also made with a vernier caliper rule. Results demonstrated the tape measure device to be easy to use and a reliable clinical assessment of lumbar flexibility.

MacRae and Wright (1969) demonstrated Shober's method of lumbar range of motion assessment to have a correlation coeffient of 0.90 with radiographic comparison and their own method to have a correlation of 0.97. The American Academy of Orthopaedic Surgeons (1965) reported the tape measure as perhaps the most accurate clinical method of measuring true motion of spinal flexion due to the conforming nature of the tape measure to the spinal curvatures.

MacRae and Wright modified a test to measure skin distraction in an attempt to evaluate spine flexibility. Having demonstrated reliability and validity, many other researchers have since used this method among other populations attaining the same results.

Inclinometer. In 1967 Loebl described "a new, simple method for accurate clinical measurement of spinal posture and movements. . . ." Forerunners of this new technique included Dunham's (1949) spondylometer for measurement of spinal movement in patients with ankylosing spondylitis, and Asmussen and Heeboll-Nielsen's (1959) inclinometric measure of spinal movement. However, Asmussen and Heeboll-Nielsen chose reference points which have little anatomical constancy or functional significance.

Loebl (1967) tested 176 men and women aged 15 to 84 years. Using an inclinometer with a 9 centimeter base each subject was measured in three positions, standing, sitting with spine flexed maximally, and prone with maximal spinal extension. The spine had previously been marked over T1, T12, midway between the T1 and T12 marks, and at S1. The results of this research indicated the inclinometer is a simple instrument designed to indicate the incline of any portion of the spine and its relation to the vertical.

Both Reynolds (1975) and Merritt, McLean, Erickson, and Offor (1986) found Loebl's method to be inferior or less practical than others to which it was compared. Reynolds studied the Dunham spondylometer and skin distraction whereas Merritt et al studied the fingertip-to-floor test and the modified Schober and Moll tests.

Mayer (1984) presented a simple, single inclinometer modification of the method of Loebl described above. Seven male and 6 female subjects aged 19 to 51 years of age, with no history of back pain within 5 years and 25 male and 13 female back pain patients aged 20 to 59 years of age participated. Erect and fully flexed postures were measured at the T12-L1 interspace with the inclinometer. With the subject remaining in the fully flexed posture the inclinometer was then placed across the thumb and forefinger of the observer who has monitored pelvic motion with his hands spanning the pelvic crests. Results of the study showed no significant difference between inclinometer and radiographic range of motion measurements. They also noted inclinometer mesurement of range of motion as a simple, effective quantitative technique for assessment.

Mayer (1985), in discussing the use of physical measurements to assess low back pain, described spinal range of motion with one and two inclinometers. He noted assessment with the single inclinometer to be more difficult. The inclinometer was placed over the sacrum in erect standing. The degree of angle was measured and a second measure was taken in the fully flexed position. The inclinometer was then placed at T12-L1 and the same measures were repeated. No subjects were tested in this research.

Keeley, Mayer, Cox, Gatchel, Smith, and Mooney (1986) used a two inclinometer technique with the same method as described by Mayer (1985) except the T12-L1 and sacral inclinometers were held on the spine simultaneously. Initial erect posture measurements and fully flexed measurements were taken. Twenty-seven males and 34 females participated in the study to investigate inter- and intraobserver reliability of the lumbar spine motion using the inclinometer technique. Inter-rater reliability of gross motion ranged from 0.90 to 0.98. Intrarater reliability of gross motion ranged from 0.91 to 0.93. Results of the inclinometer testing demonstrated a high degree of reliability of this technique.

Burdett, Brown, and Fall (1986) studied inter-tester reliability and the validity of four instruments in measuring lumbar spine curvature and pelvic tilt. Twenty-seven volunteers aged 20 to 40 years participated in the study. The modified gravity goniometer (an inclinometer with a 2.0

by 3.5 centimeter rectangular platform attached to the base of the goniometer) was used and measures made at T12-L1 and the sacrum during erect stance and full flexion. Intertester reliability for the gravity goniometer correlated with that of Keeley et al. (1986) with a correlation coefficient of 0.93 based on lumbar curvature during trunk flexion and stance.

Although the inclinometer is relatively new in its widespread use, it has been proven reliable and objective. Such an easy tool to use has become beneficial in objective measurement of flexibility for the spinal pain population. Intertester reliability is highly reliable.

CHAPTER REFERENCES

Adrichen, J. A. M. van, & Korst J. K. van der. (1973). Assessment of the flexibility of the lumbar spine. A pilot study in children and adolescents. Scandinvian Journal of Rheumatology, 2, 87.

Asmussen, E., & Heeboll-Nielsen, K. (1959). Posture, mobility, and strength of the back in boys seven to sixteen years old. Acto Orthopaedica Scandinavica, 28, 174-189.

Bohannon, R. W. (1982). Cinematographic analysis of the passive straight-leg-raising test for hamstring muscle length. Physical Therapy, 62(9), 1269-1274.

Boone D. C., & Azen, S. P. (1979). Normal range of motion of joints in male subjects. Journal of Bone and Joint Surgery, 61, 756-759.

Boone D. C., Azen, S. P., Lin, G. M. Spence, C., Baron, C., & Lee, L. (1978). Reliability of goniometric measurements. Physical Therapy, 58, 1355-1360.

Broer, M. R., & Galles, N. R. G. (1958). Importance of relationship between various body measurements in performance of the toe-touch test. The Research Quarterly, 29(2), 253-263.

Burdett, R. G., Brown, K. E., & Fall, M. P. (1986). Reliability and validity of four instruments for measuring lumbar spine and pelvic positions. Journal of the American Physical Therapy Association, 66(5), 677-684.

Cole, T. M. (1971). Goniometry: The measurement of joint motion. In F. H. Krusen (Ed.), Handbook of physical medicine and rehabilitation (2nd ed.), (pp. 40-57). Philadelphia: W. B. Saunders.

Cotton, D. J. (1972). A comparison of selected trunk flexibility tests. American Corrective Therapy Journal, 26, 24-26.

Dunham, W. F. (1949). Ankylosing spondylitis; measurements of hip and spine movements. British Journal of Physical Medicine, 12, 126.

Flint, M. M. (1963). Lumbar posture: A study of roentgenographic measurements and the influence of flexibility and strength. Research Quarterly, 34, 15-20.

Fieldman, H. (1968). Effects of selected extensibility exercises on the flexibility of the hip joint. The Research Quarterly, 37, 326-331.

Harvey, V. P., & Scott, G. D. (1967). Reliability of a measure of forward flexibility and its relation to physical dimensions of college women. The Research Quarterly, 38(1), 28-33.

Hellebrandt, F. A., Duvall, E. N., & Moore, M. L. (1949). Measurement of joint motion: Part III--reliability of goniometry. Physical Therapy Review, 29, 302-307.

Hoppenfeld, S. (1976). Physical examination of the spine and extremities. New York: Appleton-Crofts.

Israel, M. (1956). A quantitative method of estimating flexion and extension of the spine: A preliminary report. Military Medicine, 124, 181-186.

Jackson, A. W., & Baker, A. A. (1986). The relationship of the sit and reach test to criterion measures of hamstring and back flexibility in young females. The Research Quarterly for Exercise and Sport, 57(3), 183-186.

Keeley, J., Mayer, T. G., Cox, R., Gatchel, R. J., Smith, J., & Mooney, V. (1986). Quantification of lumbar function. Part V: Reliability of range of motion measures in the sagittal plane and an in vivo torso rotation measurement technique. Spine, 11(1), 31-35.

Laubach, L. L., & McConville, J. T. (1965a). Relationships between flexibility, anthropometry, and the somatotype of college men. The Research Quarterly, 37(2). 241-251.

Laubach, L. L., & McConville, J. T. (1965b). Muscle strength , flexibility, and body size of adult males. The Research Quarterly, 37(3), 384-392.

Leighton, J. R. (1955). An instrument and technique for the measurement of range of joint motion. Archives of Physical Medicine and Rehabilitation, 9, 571-578.

Lindahl, O. (1966). Determination of sagittal mobility of the lumbar spine. Acta Orthopedica Scandinavica, 37, 241-254.

Loebl, W. Y. (1967). Measurement of spinal posture and range of spinal movement. Annals of Physical Medicine, 9, 103.

Low, J. L. (1976). The reliability of joint measurement. Physiotherapy, 62, 227-229.

MacRae, I. F., & Wright, V. (1969). Measurement of back movement. Annals of Rheumatic Disease, 28, 584.

Magnusson, L. I. (1957). The effect of a specific activity program on children with low muscular fitness. Unpublished doctoral dissertation, State University of Iowa.

Mathews, D. K., Shaw. V., & Bohnen, M. (1957). Hip flexibility of college women as related to length of body segments. The Research Quarterly, 28(4), 352-356.

Mathews. D. K., Shaw, V., & Woods, J. B. (1959). Hip flexibility of elementary school boys as related to body segments. The Research Quarterly, 30(3), 297-302.

Mayer, T. G. (1985). Using physical measurements to assess low back pain. The Journal of Musculoskeletal Medicine, 2(6), 44-59.

Mayer, T. G., Tencer, A. F., Kristofferson, S., & Mooney, V. (1984). Use of noninvasive techniques for quantification of spinal range-of-motion in normal subjects and chronic low-back dysfunction patients. Spine, 9, 588-595.

McKendrick, A. (1916). Back injuries and their significance under the workmen's compensation and other acts. Edinburgh: Levingstone.

Merritt, J. L., McLean, T. J., Erickson, R. R., & Offor, K. P. (1984). Measurement of trunk flexibility in normal subjects: Reproducability of three clinical methods. Mayo Clinical Procedures, 61, 192-197.

Mitchell, W. S., Miller, J., & Sturrock, R. D. (1975). Evaluation of goniometry as objective parameter for measuring joint motion. Scottish Medical Journal, 20, 57-59.

Moll, J. M. H., & Wright, V. (1971). Normal range of spinal mobility. Annals of Rheumatic Disease, 30, 381-386.

Moore, M. L. (1949a). The measurement of joint motion. Part I: Introductory review of the literature. Physical Therapy Review, 29, 195-205.

Moore, M. L. (1949b). The measurement of joint motion. Part II: The technic of goniometry. Physical Therapy Review, 29, 256-264.

Reynolds, P. M. G. (1975). Measurement of spinal mobility: A comparison of three methods. Rheumatology Rehabilitation, 14, 180-185.

Rothstein, J. M., Miller, P. J., & Roettger, R. F. (1983). Goniometric reliability in a clinical setting. Journal of the American Physical Therapy Association, 63(10), 1611-1615.

Schober, P. (1937). The lumbar vertebral column and backache. Muenchener Medizinische Wochenschrift, 84, 336.

Scott, M. G., & French E. (1959). Measurement and evaluation in physical education. Dubuque, IA: Wm. C. Brown.

Troup, J. D. G., Hood, C. A., & Chapman, A. E. (1968). Measurements of the sagittal mobility of the lumbar spine and hips. Annals of Physical Medicine, 9(8), 308-321.

Wear, C. L. (1968). Relationship of flexibility measurements to length of body segments. Research Quarterly, 34, 234-238.

Wells, K., & Dillon, E. (1952). The sit and reach test--a test of back and leg flexibility. Research Quarterly for exercise and sport, 23, 115-118.

CHAPTER III

PROCEDURES OF THE STUDY

The information provided in this study aids to clarify procedures and instruments used in testing flexiblitiy. The procedures presented have been designed to provide maximum reliability in collecting data.

Subjects

Subjects for this study included 52 males and 52 females, 20 to 45 years of age. Each participant signed an informed consent statement to participate in the study.

Methods

Warm-up. Warm-up procedures paralleled those found in Jackson and Baker (1986). Warm-up time allows increased reliability and validity of the testing (AAHPERD Health Related Physical Fitness Test Manual 1980). The first warm-up consisted of 15 jumping jacks beginning with feet together, palms at the side jumping to feet straddled to approximately shoulder width with hands meeting over the head. A second jump returns the individual to starting position. Exercise increases blood flow to the extremities and increases body temperature to facilitate muscle extensibility. The second exercise starting position was squatting with palms of both hands flat on the floor, hips, knees, and spine flexed. The subject extended his knees keeping palms on the floor as much as possible in order to provide a slow and sustained stretch of the back and hamstring musculature. This exercise was done one time and the position was held 15 seconds.

Test Procedure. To improve validity of data collected, a counter balanced procedure was used to measure the subjects. All tests were administered within one session per subject.

TABLE V

TEST ORDER

	I	II	III	IV
Sit and Reach	1	4	3	2
Goniometer	2	1	4	3
MacRae & Wright	3	2	1	4
Inclinometer	4	3	2	1
Sample size	26	26	26	26
Males	13	13	13	13
Females	13	13	13	13

Sit and reach. The sit and reach test was performed according to instructions by the AAHPERD Test Manual. The subject started seated on the floor with feet flat against the end board of the test apparatus. Feet were shoulder width apart and knees were fully extended. Prior to subject placement the test apparatus was secured against a wall to prevent sliding away from the subject during test procedure. The subject placed his right hand on top of the left with arms extended, palms down. Fingertips were kept even. The subject then reached forward along the measuring scale which extends from the testing apparatus above the extended legs towards the subject. The subject reached four times and held the fourth reach one second which was the intended maximal reach. The score was the distance reached to the nearest centimeter. The 23 centimeter mark was where the sole of the feet met the test apparatus. The tester placed one hand on the subjects knees and gave verbal cueing to assure the subject did not flex his knees during the test. The tester read the distance of the fourth measurement at the most distant line touched by the fingertips of both hands. If the subject bent his knees or reached unevenly during the fourth trial another attempt was made. A second trial followed. (See Figure 1 in Appendix.)

Goniometric hamstring range of motion measurement. Using a method described by the American Academy of Orthopaedic Surgeons (1965), hamstring flexibility was determined for each lower extremity. The subject began supine on the floor. A one-inch mat was used for comfort when carpeting was not available during the test. The tester passively lifted the leg to be tested keeping the leg in a sagittal plane with the ipsilateral shoulder. The lifted leg rested upon the corresponding shoulder of the tester and the knee was blocked to prevent flexion with the corresponding arm. The subjects leg which was to remain flat on the floor was braced by the testers opposite leg to prevent knee, hip, and pelvic flexion. The passive range of motion was measured from a starting position of neutral or zero degrees. The end range of motion was measured in degrees of motion when the contralateral thigh began to raise, the subject indicated cessation due to discomfort, or the end feel range of motion was determined by the tester. End feel range of motion is that point where further motion is blocked by soft tissue, end of muscle stretch, or boney block. Pelvic motion was eliminated by the stabilization applied to the subject. Landmarks for goniometric measurement were according to Cole (1971). The axis of the goniometer was placed over the anteriorsuperior aspect of the greater trochanter. One arm of the goniometer was parallel to the longitudinal axis of the femur on the lateral surface of the thigh and the other arm was parallel to the floor surface. Upon completion of the testing of one leg, a re-test was performed. The test was then repeated on the contralateral leg. (See Figure 2 in Appendix.)

<u>MacRae & Wright test protocol</u>. The method of measurement described by MacRae and Wright (1969) using a plastic tape

measure was used as one measure of spinal mobility. The subject stood erect for landmarks to be located and marked. The lumbosacral junction "A" was located as described by Brunnstrom (1983). The lumbosacral junction is defined by locating the intersection of a line joining the dimples of Venus (which denote landmark of the posterior superior iliac spines) and the spine. A pen was used to mark the intersection. Using a flexible plastic tape rule calibrated in centimeters, an ink mark was placed 5 centimeters below, "B," and 10 centimeters above, "C," the initial mark indicating the lumbosacral junction. A fourth ink mark was placed at the spinous process of the seventh cervical vertebrae, "D." This cervical vertebrae is defined by Brunnstrom as the most prominent cervical spinous process, which moves as the neck is flexed.

Each subject received verbal cueing from the tester reminding him to stand straight with neck retracted in order to attempt proper spinal alignment which was denoted as the external auditory meatus perpendicular to the shoulder joint as defined by a plumb line suspended in line with a fixed point slightly anterior to the lateral malleolus (Kendall, Kendall, & Wadsworth, 1971). The distance between marks "C" and "D" were measured and remeasured. The subject was then instructed to be seated on the floor and bend forward as previously instructed for the sit and reach test. The subject was asked to additionally tuck his head as he flexed.

The distances between "B" and "D" (the total back) and "B" and "C" (the lumbar spine) were measured with the centimeter ruled tape measure. These two recorded measures indicated anterior flexion. Landmarks were remarked and a second trial followed. (See Figure 3 in Appendix.)

Inclinometer spinal measure. The single inclinometer technique is an inexpensive measure of spinal range of motion. The level of T12-L1 interspace and sacrum were marked with a pen as described by Hoppenfeld (1976). The tester stood behind the subject who was standing erect, hands at his sides. The examiner placed his hands on each side of the subjects pelvis with index fingers resting on the anterior portion of the iliac crest and thumb on the posterior portion of the iliac crest making a plane parallel to the floor. The L4-5 intervertebral space is defined as a line joining the crests of the iliac crests with the spine. Intervertebral spaces were palpated working cephalically along the spine L3-4, L2-3, L1-2, T12-L1. The sacrum was marked as previously described by locating the lumbosacral junction. Since a fixed base inclinometer was used, it was important to note the starting angle when placed on the T12-L1 interspace as well as the sacrum (Mayer, 1985). As described by Mayer (1985) the inclinometer was placed over the T12-L1 interspace. The starting range of motion was measured. The subject was instructed to flex forward maximally while maintaining knees fully extended and the maximal range of motion was recorded. The subject then returned to standing erect at which time the inclinometer was placed on the L5-S1 marking. The initial range of motion was measured. The subject was instructed to flex forward maximally while maintaining knees fully extended and the maximal range of motion was recorded. A second trial of the inclinometer spinal measure followed. (See Figure 4 in Appendix.)

Pilot Study

A pilot study was conducted to determine the reliability of the testing procedures. Ten males 20 to 45 years of age were measured on each test-retest procedure previously delineated. The following indicate the reliabilities of each test:

sit and reach	0.99
goniometry right leg	0.96
goniometry left leg	0.97
MacRae & Wright	0.90
inclinometer	0.93

Data Analysis

The data analysis included the calculations of basic descriptive statistics such as mean, standard deviation, and standard error of mean. A correlational analysis was used to determine the needed validity coefficients. Intraclass correlations were used to estimate the reliability of the data.

CHAPTER REFERENCES

American Academy of Orthopaedic Surgeons. (1965). Joint motion: method of measuring and recording. Chicago: American Academy of Orthopaedic Surgeons.

American Alliance for Health, Physical Education, Recreation, and Dance. (1980). AAHPERD health related physical fitness test manual. Washington, D. C.: AAHPERD.

Brunnstrom, S. (1983). Brunnstrom's clinical kinesiology (revised edition). Philadelphia: F. A. Davis Company.

Cole, T. M. (1971). Goniometry: The measurement of joint motion. In F. H. Krusen (Ed.), Handbook of physical medicine and rehabilitation (2nd ed.), (pp. 40-57). Philadelphia: W. B. Saunders.

Hoppenfeld, S. (1976). Physical examination of the spine and extremities. New York: Appleton-Crofts.

Jackson, A. W., & Baker, A. A. (1986). The relationship of the sit and reach test to criterion measures of hamstring and back flexibility in young females. The Research Quarterly for Exercise and Sport, 57(3), 183-186.

Kendall, H. O., Kendall, F. P., & Wadsworth, G.E. (1971). Muscles testing and function (2nd ed.). Baltimore: The Williams and Wilkins Company.

MacRae, I. F., & Wright, V. (1969). Measurement of back movement. Annals of the Rheumatic Diseases, 28, 584-589.

Mayer, T. G. (1985). Using physical measurements to assess low back pain. The Journal of Musculoskeletal Medicine, 2(6), 44-59.

Mayer, T. G., Tencer, A. F., Kristofferson, S., & Mooney, V. (1984). Use of noninvasive techniques for quantification of spinal range-of-motion in normal subjects and chronic low-back dysfunction patients. Spine, 9, 588-595.

CHAPTER IV

RESULTS

This chapter presents the statistical analysis conducted to examine the criterion related validity of the sit and reach test as a measure of hamstring and low back flexibility in adult males and females. The results include relibility coefficients, descriptive statistics, and pertinent correlations.

Relibility of the Data

Test-retests were performed for each variable measured on 52 men and 52 women. The reliability was calculated between trials for each variable. Tables VI, VII, and VIII indicate high reliability for test-retest measurements. Maximal reliability is 1.0.

TABLE VI

TEST-RETEST RELIABILITY FOR STUDY VARIABLES--TOTAL POPULATION

Variable	Test-Retest Reliability Coefficient
Sit and Reach Test	0.99
Goniometric Hamstring, Left	0.99
Goniometric Hamstring, Right	0.99
Inclinometer, Lumbar Flexion	0.98
MacRae & Wright, Total Back Flexion	0.99
MacRae & Wright, Lumbosacral Flexion	0.98

TABLE VII

TEST-RETEST RELIABILITY FOR STUDY VARIABLES--MALE POPULATION

Variable	Test-Retest Reliability Coefficient
Sit and Reach Test	0.99
Goniometric Hamstring, Left	0.99
Goniometric Hamstring, Right	0.99
Inclinometer, Lumbar Flexion	0.98
MacRae & Wright, Total Back Flexion	0.99
MacRae & Wright, Lumbosacral Flexion	0.98

TABLE VIII

TEST-RETEST RELIABILITY FOR STUDY VARIABLES--FEMALE POPULATION

Variable	Test-Retest Reliability Coefficient
Sit and Reach Test	0.99
Goniometric Hamstring, Left	0.99
Goniometric Hamstring, Right	0.99
Inclinometer, Lumbar Flexion	0.98
MacRae & Wright, Total Back Flexion	0.99
MacRae & Wright, Lumbosacral Flexion	0.99

In order to determine if one measure of hamstring flexibility was justified, the correlations between right and left leg measures were calculated. They were found to be greater than 0.93. T-tests for correlated means indicated no significant differences between right and left leg measurements. The means and standard deviations for each leg and each trial are given in Table IX. Due to these findings one hamstring flexibility measure was developed for each subject by averaging both trials and both leg measures.

TABLE IX

DESCRIPTIVE STATISTICS--GONIOMETRIC HAMSTRING

Variable Leg/Test	Mean	Standard Error of the Mean	Standard Deviation
Left 1	91.63	1.65	16.83
Left 2	91.79	1.66	17.00
Right 1	92.19	1.62	16.56
Right 2	92.75	1.63	16.63

Descriptive Statistics

A total of 104 subjects, 52 men and 52 women were tested in this study. Descriptive statistics calculated for variables included mean, standard error of the mean, and standard deviation. Statistics presented in Tables X, XI, and XII are based on average performance of each subject over both trials of each test. Goniometric hamstring is an average of both trials, both legs, as previously discussed.

TABLE X

DESCRIPTIVE STATISTICS--TOTAL POPULATION

Variable	Mean	Standard Error of the mean	Standard Deviation
Sit and Reach Test	32.23 cm	0.98	10.01
Goniometric Hamstring	92.09	1.61	16.51
Inclinometer, Lumbar Flexion	55.87	0.98	10.02
MacRae & Wright Total Back Change*	11.30 cm	0.27	2.84
MacRae & Wright Lumbosacral Change*	6.47 cm	0.11	1.17
MacRae & Wright Thoracic Change*	4.83 cm	0.25	2.54
Height	67.62 in	0.34	3.54
Weight	151.17 lb	2.84	29.02

*change represents the difference between standing and stretched postures.

TABLE XI

DESCRIPTIVE STATISTICS--MALE POPULATION

Variable	Mean	Standard Deviation
Sit and Reach Test	29.41 cm	11.43
Goniometric Hamstring	83.67	15.02
Inclinometer, Lumbar	57.01	10.30
MacRae & Wright, Total Back Change*	11.38 cm	3.54
MacRae & Wright, Lumbosacral Change*	6.56 cm	1.19
MacRae & Wright, Thoracic Change*	4.82 cm	3.16
Height	70.17 in	2.76
Weight	170.17 lb	23.85

*change represents the difference between standing and stretched positions.

TABLE XII

DESCRIPTIVE STATISTICS--FEMALE POPULATION

Variable	Mean	Standard Deviation
Sit and Reach Test	35.05 cm	7.45
Goniometric Hamstring	100.51	13.41
Inclinometer, Lumbar	54.73	9.69
MacRae & Wright, Total Back Change*	11.22 cm	1.94
MacRae & Wright, Lumbosacral Change*	6.38 cm	1.15
MacRae & Wright, Thoracic Change*	4.84 cm	1.75
Height	65.07 in	2.12
Weight	132.17 lb	19.92

*change represents the difference between standing and stretched positions.

Correlational Results

Pearson correlation coefficients were used to determine the relationship between the sit and reach test and criterion measures of hamstring and back flexibility. Results presented in Tables XIII, XIV, and XV are based on average performance of each subject over test and retest trials of each test.

TABLE XIII

PEARSON CORRELATION COEFFICIENTS BETWEEN THE SIT AND REACH TEST AND CRITERION MEASURES OF HAMSTRING AND BACK FLEXIBILITY--TOTAL POPULATION

Variables	r	r^2
Sit & Reach : Goniometric Hamstring	0.8102*	0.6564
Sit & Reach : Inclinometer, Lumbar Flexion	0.2210*	0.0488
Sit & Reach : MacRae & Wright, Total Back Change	0.2763*	0.0763
Sit & Reach : MacRae & Wright, Lumbosacral Change	0.3629*	0.1316
Sit & Reach : MacRae & Wright, Thoracic Change	0.1422	0.0202

*$p<0.05$.

TABLE XIV

PEARSON CORRELATION COEFFICIENTS BETWEEN THE SIT AND REACH TEST AND CRITERION MEASURES OF HAMSTRING AND BACK FLEXIBILITY--MALE POPLULATION

Variables	r	r^2
Sit & Reach : Goniometric Hamstring	0.8852*	0.7835
Sit & Reach : Inclinometer, Lumbar Flexion	0.2479*	0.0614
Sit & Reach : MacRae & Wright, Total Back Change	0.3325*	0.1105
Sit & Reach : MacRae & Wright, Lumbosacral Change	0.5946*	0.3535
Sit & Reach : MacRae & Wright, Thoracic Change	0.1487	0.0221

*$p<0.05$.

TABLE XV

PEARSON CORRELATION COEFFICIENTS BETWEEN THE SIT AND REACH TEST AND CRITERION MEASURES OF HAMSTRING AND BACK FLEXIBILITY--FEMALE POPULATION

Variables	r	r^2
Sit & Reach : Goniometric Hamstring	0.6998*	0.4897
Sit & Reach : Inclinometer, Lumbar Flexion	0.3067*	0.0940
Sit & Reach : MacRae & Wright, Total Back Change	0.1991	0.0396
Sit & Reach : MacRae & Wright, Lumbosacral Change	0.1173	0.0206
Sit & Reach : MacRae & Wright, Thoracic Change	0.1437	0.0206

*p<0.05.

CHAPTER V

DISCUSSION AND CONCLUSIONS OF THE STUDY

The sit and reach test was determined to be a valid test of back and leg flexibility as indicated by a validity coefficient of 0.90 with the standing toe touch test (Wells & Dillon, 1952). Due to this high validity, the sit and reach test was chosen by the American Alliance of Health, Physical Education, Recreation, and Dance to become the field test measure used to evaluate low back and hamstring flexibility (AAHPERD, 1980). The purpose of this study was to determine the relative contribution of low back and hamstring flexibility to the sit and reach test in adults. Prior to this study only one other has examined the influence of these variables on such a widely used measure as the sit and reach test (Jackson & Baker, 1986). The need to further study the relative contribution of hamstring and low back flexibility to the sit and reach test prompted this investigation.

The results of this study indicate hamstring flexibility is highly related to the sit and reach test for the total population and males. The correlation coefficients were 0.81 and 0.88 respectively. Hamstring flexibility is only moderately related to the sit and reach test in females. The correlation coefficient was 0.69.

This study also indicates low back flexibility has a low correlation with the sit and reach test in the total population and females as measured by the MacRae and Wright protocol. Correlation coefficients were 0.36 and 0.11 respectively. Low back flexibility had a moderate relationship to the sit and reach test in males. The correlation coefficient was 0.59. Correlation between MacRae and Wright measures and the sit and reach test relate the amount in change between standing and stretched postures to the sit and reach test. Correlations between inclinometer test of lumbar flexibility and the sit and reach, however, relate the actual degrees of motion to the field test. As measured with the inclinometer, low back flexibility has a minimal relationship with the sit and reach test in total population, males, and females. Correlation coefficients were 0.22, 0.24. and 0.30 respectively.

Testing procedures used in this study were found to be highly reliable. Correlation coefficients for the sit and reach test, goniometric hamstring, inclinometer, and MacRae & Wright test were all 0.98 to 0.99 on a maximal scale of 1.0. The sit and reach test reliability of 0.99 obtained compares favorably with Wells and Dillon (1952), 0.98; Jackson and Baker (1986), 0.99; and others including Mathews et al. (1957, 1959), and Wear (1963). Hamstring test-retest reliability of 0.99 compares favorably with Jackson and Baker (1986), 0.99; Bohannon (1982), 0.99; and Troup et al. (1968), 0.85, left and 0.84, right. It further agrees with test-retest reliability of joint flexibility regardless of method, goniometer or flexometer. Leighton (1955), Troup et al. (1968), Mitchell et al. (1975), Boone et al. (1978), and Rothstein et al. (1983) all document high test-retest reliability. Spinal flexibility reliability ranged from 0.98 to 0.99.

The findings of this study are similar to those of Jackson and Baker (1986) relative to the female population. Jackson and Baker found hamstring flexibility to be moderately related to the sit and reach test (0.59 and 0.64) in females 13 to 15 years of age. This study found adult females aged 20 to 45 years with a moderate relationship of 0.69. Jackson and Baker further report the sit and reach test to be an invalid measure of low back flexibility in the same population, correlation coefficient of 0.27. This study demonstrated a similar low correlation of 0.11 in adult females.

Conclusions

1. In males 20 to 45 years:
   a. The sit and reach test is a valid measure of hamstring flexibility.
   b. The sit and reach test has questionable validity as a measure of low back flexibility.
2. In females 20 to 45 years:
   a. The sit and reach is a moderately valid measure of

hamstring flexibility.

b. The sit and reach is not a valid measure of low back flexibility.

Recommendations

The findings of this study are generalizable to men and women 20 to 45 years of age. Similar findings between women of this age and females 13 to 15 have now been documented. Because males did not replicate female data it is recommended that further studies examine flexibility scores of boys. Other investigations which examine the elderly may also confirm these findings which appear sex related. Due to ease of use, further studies of the inclinometer as a tool for field study is also recommended.

CHAPTER REFERENCES

American Alliance for Health, Physical Education, Recreation, and Dance. (1980). AAHPERD health related physical fitness test manual. Washington, D. C.: AAHPERD.

Bohannon, R. W. (1982). Cinematographic analysis of the passive straight-leg-raising test for hamstring muscle length. Physical Therapy, 62(9), 1269-1274.

Jackson, A. W., & Baker, A. A. (1986). The relationship of the sit and reach test to criterion measures of hamstring and back flexibility in young females. The Research Quarterly for Exercise and Sport, 57(3), 183-186.

Leighton, J. R. (1955). An instrument and technic for the measurement of range of joint motion. Archives of Physical Medicine and Rehabilitation, 9, 571-578.

Mathews, D. K., Shaw, V., & Bohnen, M. (1957). Hip flexibility of college women as related to length of body segments. The Research Quarterly, 28(4), 352-356.

Mathews, D. K., Shaw, V., & Woods, J. B. (1959). Hip flexibility of elementary school boys as related to body segments. The Research Quarterly, 30(3), 297-302.

Mitchell, W. S., Miller, J., & Sturrock, R. D. (1975). Evaluation of goniometry as objective parameter for measuring joint motion. Scottish Medical Journal, 20, 57-59.

Troup, J. D. G., Hood, C. A., & Chapman, A. E. (1968). Measurements of the sagittal mobility of the lumbar spine and hips. Annals of Physical Medicine, 9(8), 308-321.

Wear, C. L. (1963). Relationship of flexibility measurements to length of body segments. Research Quarterly, 34, 234-238.

Wells, K., & Dillon, E. (1952). The sit and reach test--A test of back and leg flexibility. Research Quarterly for Exercise and Sport, 23, 115-118.

APPENDIX

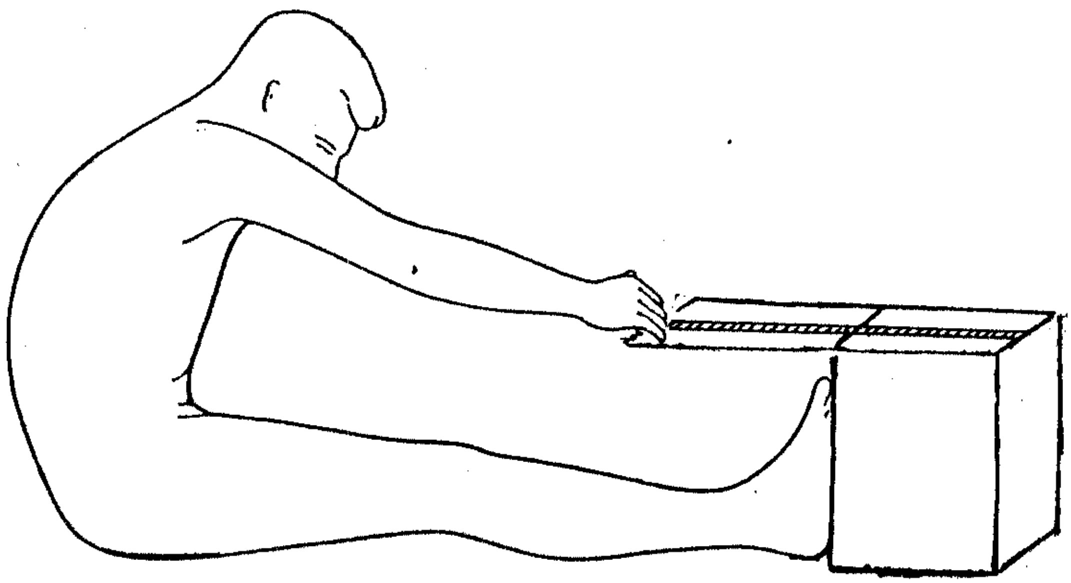

Fig. 1--Sit and Reach Test

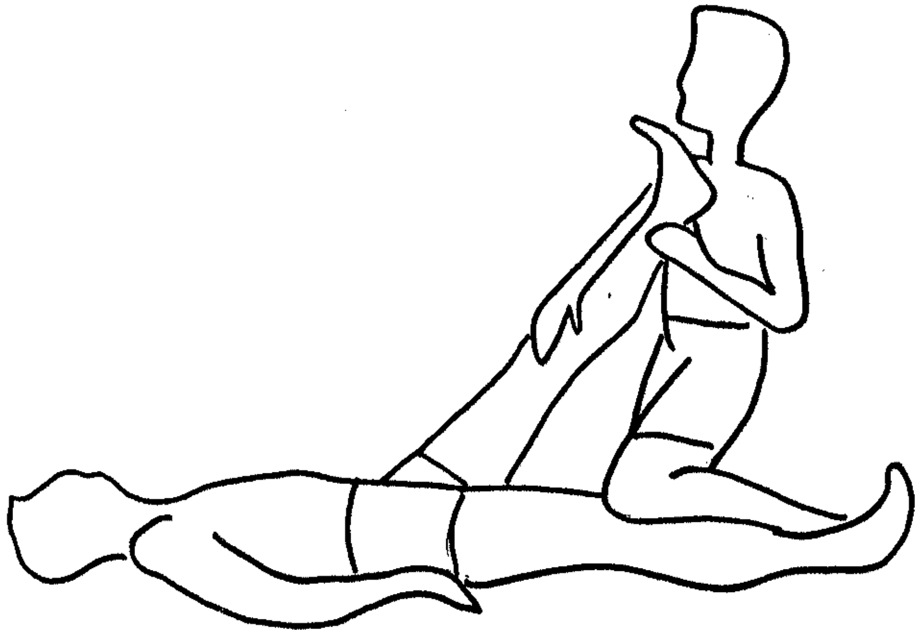

Fig. 2--Goniometric Hamstring Measure

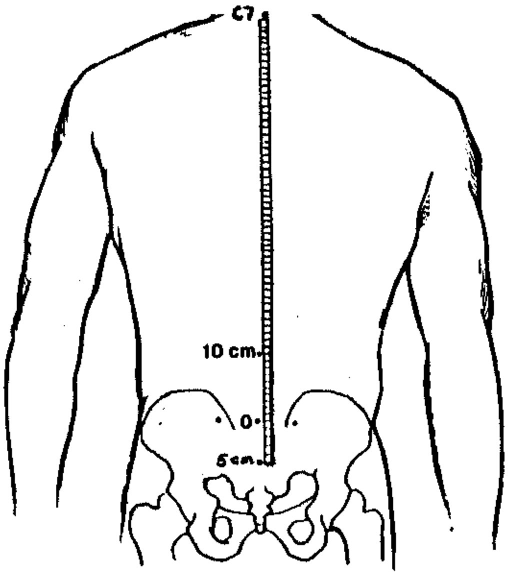

Fig. 3a--MacRae & Wright Markings

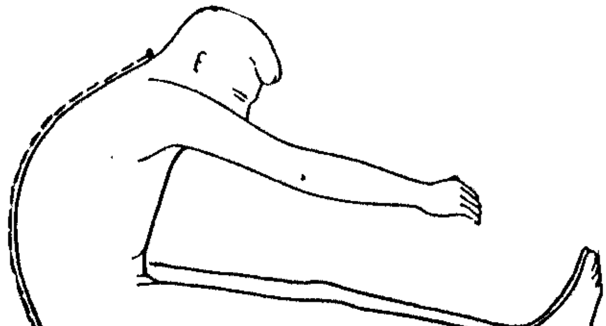

Fig. 3b--MacRae & Wright Procedure

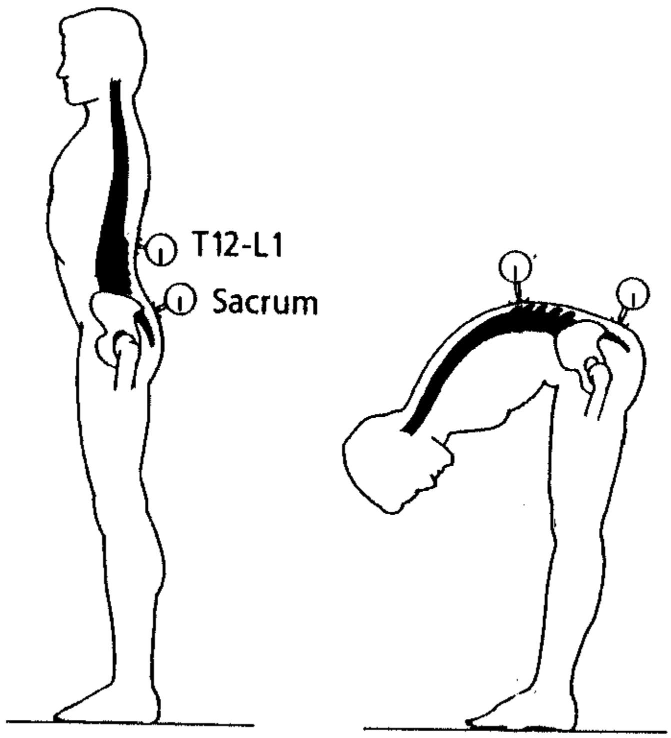

Fig. 4--Inclinometer Procedure

BIBLIOGRAPHY

Books

American Academy of Orthopaedic Surgeons. (1965). Joint motion of measuring and recording. Chicago: American Academy of Orthopaedic Surgeons.

American Alliance for Health, Physical Education, Recreation, and Dance. (1980). AAHPERD health related physical fitness test manual. Washington, D. C.: AAHPERD.

Brunnstrom, S. (1983). Brunnstrom's clinical kinesiology (revised edition). Philadelphia: F. A. Davis Company.

Cole, R. M. (1971). Goniometry: The measurement of joint motion. In F. H. Krusen (Ed.), Handbook of physical medicine and rehabilitation (2nd ed.) (pp. 40-57). Philadelphia: W. B. Saunders.

Hoppenfeld, S. (1976). Physical examination of the spine and extremities. New York: Appleton-Crofts.

Kendall, H. O., Kendall, F. P., & Wadsworth, G. E. (1971). Muscles testing and function (2nd ed.). Baltimore: The Williams and Wilkins Company.

McKendrick. A. (1916). Back injuries and their significance under the workmen's compensation and other acts. Edinburgh: Levingstone.

Scott, M. G., & French, E. (1959). Measurement and evaluation in physical education. Dubuque, IA: Wm. C. Brown.

Articles

Adrichen, J. A. M. van, & Korst J. K. van der. (1973). Assessment of the flexibility of the lumbar spine. A pilot study in children and adolescents. Scandinvian Journal of Rheumatology, 2, 87.

Asmussen, E., & Heeboll-Nielsen, K. (1959). Posture, mobility, and strength of the back in boys seven to sixteen years old. Acto Orthopaedica Scandinavica, 28, 174-189.

Bohannon, R. W. (1982). Cinematographic analysis of the passive straight-leg-raising test for hamstring muscle length. Physical Therapy, 62(9), 1269-1274.

Boone D. C., & Azen, S. P. (1979). Normal range of motion of joints in male subjects. Journal of Bone and Joint Surgery, 61, 756-759.

Boone D. C., Azen, S. P., Lin, G. M., Spence, C., Baron, C., & Lee, L. (1978). Reliability of goniometric measurements. Physical Therapy, 58, 1355-1360.

Broer, M. R., & Galles, N. R. G. (1958). Importance of relationship between various body measurements in performance of the toe-touch test. The Research Quarterly, 29(2), 253-263.

Burdett, R. G., Brown, K. E., & Fall, M. P. (1986). Reliability and validity of four instruments for measuring lumbar spine and pelvic positions. Journal of the American Physical Therapy Association, 66(5), 677-684.

Cotton, D. J. (1972). A comparison of selected trunk flexibility tests. American Corrective Therapy Journal, 26, 24-26.

Dunham, W. F. (1949). Ankylosing spondylitis; measurements of hip and spine movements. British Journal of Physical Medicine, 12, 126.

Flint, M. M. (1963). Lumbar posture: A study of roentgenographic measurements and the influence of flexibility and strength. Research Quarterly, 34, 15-20.

Fieldman, H. (1968). Effects of selected extensibility exercises on the flexibility of the hip joint. The Research Quarterly, 37, 326-331.

Harvey, V. P., & Scott, G. D. (1967). Reliability of a measure of forward flexibility and its relation to physical dimensions of college women. The Research Quarterly, 38(1), 28-33.

Hellebrandt, F. A., Duvall, E. N., & Moore, M. L. (1949). Measurement of joint motion: Part III--reliability of goniometry. Physical Therapy Review, 29, 302-307.

Israel, M. (1956). A quantitative method of estimating flexion and extension of the spine: A preliminary report. Military Medicine, 124, 181-186.

Jackson, A. W., & Baker, A. A. (1986). The relationship of the sit and reach test to criterion measures of hamstring and back flexibility in young females. The Research Quarterly for Exercise and Sport, 57(3), 183-186.

Keeley, J., Mayer, T. G., Cox, R., Gatchel, R. J., Smith, J., & Mooney, V. (1986). Quantification of lumbar function. Part V: Reliability of range of motion measures in the sagittal plane and an in vivo torso rotation measurement technique. Spine, 11(1), 31-35.

Kendall, F. P. (1965). A Criticism of current tests and exercises for physical fitness. Journal of the American Physical Therapy Association, 45(3), 187-197.

Kraus, H., & Hirschland, R. P. (1950). Minimum muscular fitness tests in school children. The Research Quarterly, 21, 25-33.

Laubach, L. L., & McConville, J. T. (1965a). Relationships between flexibility, anthropometry, and the somatotype of college men. The Research Quarterly, 37(2). 241-251.

Laubach, L. L., & McConville, J. T. (1965b). Muscle strength , flexibility, and body size of adult males. The Research Quarterly, 37(3), 384-392.

Leighton, J. R. (1955). An instrument and technique for the measurement of range of joint motion. Archives of Physical Medicine and Rehabilitation, 9, 571-578.

Lindahl, O. (1966). Determination of sagittal mobility of the lumbar spine. Acta Orthopedica Scandinavica, 37, 241-254.

Loebl, W. Y. (1967). Measurement of spinal posture and range of spinal movement. Annals of Physical Medicine, 9, 103.

Low, J. L. (1976). The reliability of joint measurement. Physiotherapy, 62, 227-229.

MacRae, I. F., & Wright, V. (1969). Measurement of back movement. Annals of Rheumatic Disease, 28, 584.

Mathews, D. K., Shaw. V., & Bohnen, M. (1957). Hip flexibility of college women as related to length of body segments. The Research Quarterly, 28(4), 352-356.

Mathews. D. K., Shaw, V., & Woods, J. B. (1959). Hip flexibility of elementary school boys as related to body segments. The Research Quarterly, 30(3), 297-302.

Mayer, T. G. (1985). Using physical measurements to assess low back pain. <u>The Journal of Musculoskeletal Medicine</u>, <u>2</u>(6), 44-59.

Mayer, T. G., Gatchel, R. J., Kishino, N., Keeley, J., Capra, P., Mayer, H., Barnett, J., & Mooney, V. (1985). Objective assessment of spine function following industrial injury. A prospective study with comparison group and one-year follow-up. <u>Spine</u>, <u>10</u>(6), 482-493.

Mayer, T. G., Tencer, A. F., Kristofferson, S., & Mooney, V. (1984). Use of noninvasive techniques for quantification of spinal range-of-motion in normal subjects and chronic low-back dysfunction patients. <u>Spine</u>, <u>9</u>, 588-595.

Merritt, J. L., McLean, T. J., Erickson, R. R., & Offor, K. P. (1984). Measurement of trunk flexibility in normal subjects: Reproducability of three clinical methods. <u>Mayo Clinical Procedures</u>, <u>61</u>, 192-197.

Mitchell, W. S., Miller, J., & Sturrock, R. D. (1975). Evaluation of goniometry as objective parameter for measuring joint motion. <u>Scottish Medical Journal</u>, <u>20</u>, 57-59.

Moll, J. M. H., & Wright, V. (1971). Normal range of spinal mobility. <u>Annals of Rheumatic Disease</u>, <u>30</u>, 381-386.

Moore, M. L. (1949a). The measurement of joint motion. Part I: Introductory review of the literature. <u>Physical Therapy Review</u>, <u>29</u>, 195-205.

Moore, M. L. (1949b). The measurement of joint motion. Part II: The technic of goniometry. <u>Physical Therapy Review</u>, <u>29</u>, 256-264.

Pate, R. R. (1983). A new definition of youth fitness. <u>The Physician and Sports Medicine</u>, <u>11</u>(4), 77-83.

Reynolds, P. M. G. (1975). Measurement of spinal mobility: A comparison of three methods. <u>Rheumatology Rehabilitation</u>, <u>14</u>, 180-185.

Rothstein, J. M., Miller, P. J., & Roettger, R. F. (1983). Goniometric reliability in a clinical setting. <u>Journal of the American Physical Therapy Association</u>, <u>63</u>(10), 1611-1615.

Schober, P. (1937). The lumbar vertebral column and backache. <u>Muenchener Medizinische Wochenschrift</u>, <u>84</u>, 336.

Troup, J. D. G., Hood, C. A., & Chapman, A. E. (1968). Measurements of the sagittal mobility of the lumbar spine and hips. Annals of Physical Medicine, 9(8), 308-321.

Wear, C. L. (1968). Relationship of flexibility measurements to length of body segments. Research Quarterly, 34, 234-238.

Wells, K., & Dillon, E. (1952). The sit and reach test--a test of back and leg flexibility. Research Quarterly for exercise and sport, 23, 115-118.

Unpublished Material

Magnusson, L. I. (1957). The effect of a specific activity program on children with low muscular fitness. Unpublished doctoral dissertation, State University of Iowa.