COMPARISON OF LUMBAR CURVES, WHEN SITTING ON THE NADA-CHAIR, SITTING ON A CONVENTIONAL CHAIR AND STANDING

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ABSTRACT

The purpose of this study was to test if the lumbar curve produced with the Nada-Chair while writing at a desk more closely approximated the lumbar curve produced in standing than did writing at a desk with a conventional chair (CC). This study also compared the number of subjects exhibiting extension versus flexion between the Nada-Chair and the CC.

All subjects were volunteers without low back pain. The 30 subjects were physical therapy students from Beaver College, between 20 and 42 years old. A flexible ruler was used to measure the lumbar curve from Ll to S2 in each of the following positions: standing, sitting in a CC, and sitting in the Nada-Chair. G one-way analysis of variance (ANOVA) with repeated measures, and a student Newman-Keuls test was used to determine the difference among the three positions. A significant difference among the means of the degrees of lumbar curvature was found ($p < .001$). The lumbar curve produced by the Nada-Chair more closely approximated the standing lumbar curve than did the cc. A chi square analysis was used to determine if there was a difference between the number of subjects exhibiting flexion versus extension in the Nada-Chair as compared to the CC. The results showed there were significantly more subjects in extension in the Nada-Chair than in the CC ($p < .02$).

The results suggest that the Nada-Chair can be recommended by physical therapists when lumbar extension in sitting is indicated for the prevention of low back pain.

INTRODUCTION

Low back pain is a major medical problem affecting 50 - 80% of the American population. (1.2) The cost of medical treatment has been estimated to be 4 billion dollars, and the price of work compensation to be 10 billion dollars. (2) In Sweden and other industrialized countries, low back pain is a major reason for disability and absenteeism from work. (3.4) In addition, the impact of low back pain is felt in its ability to compromise the quality of life for those afflicted. Among chronic conditions, impairments of the back and spine are the most frequent causes of limitation of activity in people under 45 years old. (2)

Prolonged sitting in a conventional chair, one that produces a 90 degree angle between the thigh and trunk, has been associated with low back pain. (5,6,7,8,9) This position allows the pelvis to posteriorly rotate, resulting in a flattening of the normal lumbar curve found in standing. (5,7) This flattening or flexion during sitting has been associated with overstretching of the posterior ligamentous structures and paraspinal muscles. (8) and with disc herniation. (10) These are all common causes of low back pain. Many researchers have suggested that these problems can be prevented by maintaining a lordotic curve while sitting. They advocate designing a chair with a lumbar support to achieve this goal. (4,7,11,12,13,14,15)

Several epidemiological studies indicate a relationship between sitting and low back problems. One such study found that in sedentary occupations, the risk for herniated lumbar discs was increased in people over 35. (16) Occupations that require prolonged driving show a particularly high risk. Another study looked at factors associated with low back pain in various occupations. They suggested that prolonged sitting of bus drivers was related to low back pain. (9)

The majority of people in today's industrialized society spend an enormous amount of time sitting. One author described the typical working day. He said people sit as they drive to work, they spend the majority of their work day sitting, and finally they come home to sit in front of the television for the rest of the evening. (17) Mandal cleverly proposed that man should be classified now as Homo Sedens. (1) Despite the huge amount of time that people spend sitting, the majority of chairs used today are of the conventional type. These chairs promote improper posture that is associated with low back pain. (7)

Recently there have been chairs designed with proper lumbar support. However, in most of these chairs the effect of the lumbar support is lost when working in the forward leaning position. The manufacturers of the Nada-Chair Hack:: Sling* claim that it promotes good sitting posture by stabilizing the pelvis from posterior rotation, thereby preventing the slumped (flexed) posture. (18) The Nada-Chair is a frameless chair, consisting of a pad which fits against the lower back and two connecting straps which go around the knees (see Figure 1 in appendix). * Nada-Chair, 2448 Larpenteur Ave., Saint Paul, MN 55113

However, there has been no research performed to support these claims. This study will be based on the widely accepted extension theory that the natural lumbar curve created in standing is the correct posture for sitting. (4,5,19,20) We will determine if there is a difference in the lumbar curve produced when sitting in a Nada-Chair, as compared to sitting in a conventional chair and also compared to standing. If the Nada-Chair can be shown to correct poor posture (increase lumbar extension), while working in the forward leaning position, then physical therapists can recommend it to decrease the incidence of low back pain.

LITERATURE REVIEW

It is commonly recognized that most lower back problems arise from postural factors related to sitting. (5,6,7,8,9) There are two major theories about the correct sitting posture, the flexion theory and the extension theory. The flexion theory supports a flat-backed sitting position, while the extension theory supports sitting with the lumbar spine in extension.

Proponents of the flexion theory believe that a lumbar lordotic curve present in standing and sitting will increase the compressive force or stress on the posterior portion of the disc. They therefore promote posture that increases lumbar flexion which will in turn reduce the pressure on the posterior structures of the lumbar spine. (21,22) However, there is little evidence to support this theory. The more widely accepted theory is the extension theory. It states that the optimal sitting posture is that which reestablishes the natural lordosis found while standing and promotes upright trunk and head position. (4,5,20) This position does not require considerable muscle work and does not over stretch the muscles and ligaments. (19)

There is a substantial amount of evidence to support the extension theory. Observation has shown that there is a natural curve in the lumbar spine in the standing position. When moving from standing to sitting in a conventional chair, the knees and hips flex, the pelvis rotates backwards and the lumbar spine flexes to a flattened position. (5,7,23) In a study conducted by Anderson et al. it was found that moving from a standing position to an unsupported sitting position caused the lumbar lordosis to be decreased by an average of 38 degrees. This occurred primarily by rotation of the pelvis (an average of 28 degrees).

The remaining 10 degrees occurred by decreasing the angle between the lumbar vertebral bodies. (23) Anderson et al. found the disc pressure of the third lumbar disc to increase as the lumbar spine moved from a position of lordosis to kyphosis. (11) The flat-backed sitting posture, when adopted for prolonged periods of time, has been correlated with painful overstretching and pathological changes to the associated posterior structures of the lumbar spine. (7)

A proposed mechanism for low back pain is stress on the posterior ligaments and muscles of the low back produced in sitting. When sitting in a conventional chair, the thigh trunk angle is 90 degrees. (24) Because the hamstring and gluteal muscles are attached to the thigh and pelvis, the tension in these muscles creates a posterior rotational moment of the pelvis, which leads to flattening of the lumbar spine. (7)

Initially, when sitting, the paraspinal muscles work against this tension to maintain the lumbar curve. However, because of the increased load these muscles must support, they fatigue after a few minutes, and the spine moves into a position of kyphosis. (8)

Anderson found that in this position, there is a decrease in activity of the deep back muscles, leaving the ligaments and joints to support the back. (11) Overstretching of there posterior ligaments and paraspinal muscles in prolonged sitting causes the firing of the nocioceptors resulting in lower back pain. Over time, this stress on the ligaments and joints can lead to damage. (8,20)

Postural factors, in particular sitting with the lumbar spine flexed, have also been implicated in disc herniation. According to a study by Kelsey, people who sat at their jobs for more than half of the time had a 50-60% higher risk of developing a herniated lumbar disc over those who sat less than half of the time. (10) Schoberth found that in sitting, the lumbar flexion movement occurred in the fourth and fifth lumbar discs. (25) This may explain why most IV disc herniations occur at the L4 or L5 level. (1,7)

A proposed mechanism for disc herniation is that the annulus fibrosis, surrounding the nuclear pulposus of the lumbar intervertebral disc, is compressed anteriorly and stretched posteriorly during flexion of the lumbar spine in sitting. The fibers of the annulus begin to degenerate and tear at the age of 25. (26) This is consistent with the fact that low back pain often starts around age 25. (2) Repeated flexion of the lumbar spine in sitting can lead to microtraumas and eventually degeneration of the posterior annulus fibrosis. (5) Nachemson, et. al. found that during unsupported sitting (sitting with no back or arm support and the lumbar spine in a flexed position) the intradiscal pressure between L3 and L4 is increased by 40% as compared to the pressure found in standing. (27) This increased intradiscal pressure can force the nucleus pulposus out through tears in the degenerated annulus fibrosis. The nucleus pulposus is most frequently pushed posteriorly against the posterior longitudinal ligament (PLL). When the nucleus pulposus is pushed against the PLL, it results in painful stretching of this ligament which causes midline back pain. (7,8) Since the PLL is weakest posteriolaterally, the nucleus pulposus often herniates in this direction into the intervertebral foramen and compresses the nerve root. One of the nerve roots of the sciatic nerve is commonly compressed. This results in pain in the corresponding spinal segment distribution and can eventually lead to impaired reflexes and motor weakness. (26)

Advocates of the extension theory believe that the above mentioned problems, caused by lumbar flexion, can be prevented by maintaining the lumbar lordosis when sitting. Many researchers advocate the use of some form of lumbar support when sitting to maintain the lumbar lordosis and prevent low back problems. (4,7,11,12,13,14,15). Akerbolm showed that the myoelectric activity of the paraspinal muscles is reduced with the use of a lumbar support in sitting, as compared to the flat back sitting position. (15) Anderson et al. measured the IV disc pressure between L5 and L4 of subjects sitting in an experimental chair. The chair consisted of a back rest angled at 90 degrees with an attached small cylindrical lumbar support located at L3. The distance between the back rest and the back support could be adjusted. They found, as this distance was increased to four cm, the IV disc pressure between L3 and L4 decreased. (11) Anderson et al. in a later study used the same experimental chair with the lumbar support placed four centimeters from the back rest.

Using radiography, they found an average lumbar lordosis of 46.8 degrees with the lumbar support. In unsupported sitting they found the average lumbar lordosis to be 22.2 degrees. The 46.8 degree curve found with the lumbar support more closely approximated the average lumbar lordosis of 59.8 degrees found in the standing position. (23) Based on these two studies, Anderson recommended that chairs should be designed with adequate lumbar support. (11,25) Keegan et al. took x-rays of normal subjects while sitting in a chair with the trunk-thigh angle at 90 degrees: this is the position created by most conventional chairs. They found a considerable flattening of the lumbar curve. They recommended that chairs should be designed with the back support primarily over the lumbar region, to restore the lordotic curve and protect the lower lumbar IV discs. (7) The surface of this back support should be convex and conform to the natural lordosis. (7,17) McKenzie promotes the use of a lumbar roll when sitting in a seat with a back rest. To provide optimal lordosis, he recommends placing the lumbar roll at or just above the belt line, approximately in the area of L3 and L4. The sacrum should be against the back of the chair. McKenzie claims to have clinical success with this method. (8)

Mandal and others have suggested using a tilted seat to promote good sitting posture. (19,24,28,29) Their rationale is based on the work of Keegan, who found that a thigh trunk angle of 135 degrees in sitting will preserve the lumbar lordosis. (7)

One chair designed to produce this posture was developed by the Norwegians, called the Westnofa Balans Multi-Chair (BMC). This chair has a forward seat slope of 20 degrees, and knee pads to provide support. Frey and Tecklin found that while sitting and writing, the BMC caused less lumbar flexion than a conventional chair. They also found that the BMC better approximated the natural standing lumbar curve than a conventional chair. (12)

Drury and Francher conducted a study to assess the comfort of a chair similar to the BMC. They found that overall comfort was not better than a conventional chair. The major complaints were pain in the knees and shins. (79)

Today more people are including ergonomic principles in the design of chairs. For example, many office chairs are designed with an adjustable back rest to provide lumbar support. However, it has been observed that while sitting at a desk, many people lean forward to perform such tasks as reading, writing, and assembling. (1) In this position, any potential benefits of a lumbar support are negated. In addition, it was found that leaning forward while maintaining the lumbar lordosis creates less disc pressure than leaning forward with the low back flexed. (11)

This points out the need to design chairs similar to the BMC that would promote lumbar lordosis while working and leaning forward.

As stated earlier, the manufacturers of the Nada-Chair claim that their product promotes proper sitting posture by preventing posterior rotation of the pelvis. This would prevent the slouched (flexed) sitting position of the lower back. They also claim that the Nada-Chair provides lumbar support when sitting and working in the forward leaning position. (18)

Research is needed to determine the validity of these claims. We will base our study on the widely accepted extension theory that the natural lumbar curve present in standing is the correct posture for sitting. We will measure and compare the lumbar curves created when writing and sitting in a conventional chair, writing and sitting with the Nada-Chair, and standing. We hypothesize that the amount of lumbar extension created by the Nada-Chair will be closer to the amount produced in standing than that produced in a conventional chair.

All subjects were volunteers from the Beaver College student body. Both male and female subjects were allowed to participate. The age range, 20 to 42 years old, was determined by a sample of convenience. Volunteers with any of the following characteristics were excluded: currently under a physician's care for any back problem, history of back injury or surgery, arthritis, lower extremity circulatory problems, or any recent back injuries.

Equipment

Each subject's lumbar curve was measured when sitting in the Nada-Chair Back Sling. This frameless chair consists of a pad which fits against the lower back and 2 connecting straps which go around the knees (see Fig. 1 in appendix). Each strap has a pad which fits on the anterior/proximal portion of the tibia. Tightening the straps increases the tension applied by the lumbar pad to the back. All subjects were weighed to determine the tension used on the straps of the Nada-Chair. Pressure under the knee-pads of the Nada-Chair was measured using a pressure evaluator **. This device is commonly used for measuring seating pressure. (It consists of an inflatable plastic pouch with two pieces of copper inside. These wires are connected to a circuit which incorporates a buzzer. When the pouch is inflated, the wires are separated: however, with increased pressure on the pouch, the wires are approximated and the buzzer is sounded.)

** Scimedics Incorporated, 1661 Market St. Corona, CA 91720

A flexible ruler (curve) was used to measure the lumbar curvatures. This ruler is a bendable metal band encased in pliable plastic. Subjects sat in a conventional chair (CC). measuring 39 cm in height and 41 cm in depth. Subjects were writing at a conventional desk, 74 cm in height.

Procedure

The lumbar curvatures for each subject were measured in the following conditions: standing; sitting on a CC and writing at a desk; and sitting using a Nada-Chair and writing at a desk. Each subject's weight was recorded and used to determine the tension in the Nada-Chair straps. The lumbar curves were measured using the flexible ruler technique. In order to expose the low back area, females were asked to wear shorts and a halter top. Males were asked to wear shorts and no shirt. For each condition, the spinous processes of the lower back were palpated and Ll to S2 were marked with stickers. The spinous processes of S2 was assumed to be midway between the posterior superior iliac spines (PSIS's). The PSIS's were palpated and marked with stickers. A third sticker was placed on an imaginary line between the PSIS's to mark the spinous process of

S2. The spinous process of Ll was located using the following method. The L4-L5 interspace was located on an imaginary line approximately midway between the superior aspect of the two iliac crests. The spinous process of Ll was then found by palpating 4 spinous processes up from this space. (10) To measure the lumbar curve, the end of the ruler was placed on S2 and molded over the skin covering the previously marked spinous processes. The level of Ll was marked with tape on the flexible ruler. After molding the flexible ruler to the shape of the lumbar curve, the obtained curve was traced on paper for later analysis. Our intratester reliability of the flexible ruler measurement was found to have a .92 ICC value. Lovell et al found the intratester reliability coefficient of this method for one tester to be .84 and for a second tester to be .73 for subjects without low back pain. For subjects with low back pain, the intratester reliability coefficients of .94 and .83 were reported by the two testers respectively. (30) Rose and Hart found the intratester reliability coefficient of this method to be r=.97. In addition, they demonstrated the validity of the technique by finding a high correlation between the lumbar curvatures found using x-rays and the flexible ruler (r=.87}. (31)

For the first measurement, the subjects were asked to remove their shoes and stand while the spinous processes of LI and S2 were marked with stickers. The subjects were asked to assume their normal standing position, and the lumbar curve was measured after the subject reported being comfortable. The order of the next two measurements, sitting in the CC and sitting in the Nada-Chair, was randomized. When measuring the lumbar curve of the subjects sitting in the CC, palpation of the spinous processes was repeated, and the stickers were readjusted if needed. The stickers were later used to locate the spinous processes by touch when using the Nada-Chair because the lumbar pad covered Ll and S2. The lumbar curve was measured after the subject began writing at the desk and reported being comfortable.

When using the Nada-Chair, the subject remained seated in the CC. The pressure bulb was taped over the left tibial tuberosity. The Nada-Chair was placed on the subject with the superior edge of the back pad placed between the spinous processes of Tl2 and Ll. The left knee pad of the Nada-Chair was adjusted over the pressure bulb. The subjects were instructed to adjust the Nada-Chair according to the manufacturer's instructions. These instructions state to tighten the straps by leaning forward until the back pad is snug against the lower back and maximum comfort is obtained without fatigue or tingling around the knees. A pressure reading was taken while the subject was writing. If the pressure reading did not fall within the individual's standard pressure range, the tension in the straps was readjusted. This standard pressure range was determined in a pilot study which is described at the end of this section. The process was repeated until the pressure fell within the individual’s standard pressure range and the subject reported being comfortable. In all cases the subjects reported being comfortable within their pressure range. Next, the flexible ruler was inserted under the back pad and pressure applied through the back pad to conform the ruler to the lumbar curve. The pilot study to determine the standard pressure ratio of the tension in the Nada-Chair consisted of six subjects. Each subject was weighed. They sat with the Nada-Chair and adjusted it according to the manufacturer's instructions. The ratio between the subject’s weight and the pressure under the knee pad was determined. The mean of these six ratios was approximately 1:1 . Therefore, in the actual study, the subjects’ body weight was used to determine the pressure for adjusting the tension in the Nada-Chair straps. When adjusting the tension in the straps in the actual study, the pressure range for each individual was calculated with the equation: body weight +.12 body weight. The SD of the six ratios in the pilot study was .l0; however, a range of + .12 body weight was used to obtain a wider pressure range that allowed for individual comfort.

Data Analysis

The degree of lumbar curvature was calculated according to the procedure described by Rose and Hart. (15) The trace of the lumbar curve from Ll to S2 obtained from the flexible ruler was analyzed (see figure 3). The length of the cord ( ) between Ll and S2 was measured, as well as the perpendicular distance (h) from the center of the cord (/2) to the curve. The angle of the lumbar curve was determined by using the formula: = 4 arctan (2h/) (see Figure 2, in appendix). The difference in mean degree of lumbar curve among the three positions was analyzed using a 1-way Analysis of Variance (ANOVA) with repeated measures. A Newman-Keuls post-hoc test was used to compare the three pairs of means of the positions. A chi-square test was used to determine if there were significant differences between the number of subject's exhibiting flexion versus extension in the Nada-Chair and in the conventional chair. This test was done for curves obtained with the Nada-Chair and for those obtained with the conventional chair.

RESULTS

The results of the one-way analysis of variance (ANOVA) for repeated measures showed a significant difference among the means of the degrees of lumbar curvature in the three positions: standing; sitting in the CC; and sitting in the Nada-Chair, ($F = 213.98$: $df = 2,58$: $p < .OOl$) (see Table 1). The Student Newman-Keuls post-hoc test showed a significant difference between all the pairs of the means for the three positions ($p <.01$ see Table 2). The mean for the lumbar curve obtained in standing was 46.70 degrees, with a range of 20.5 to 72.0 degrees. The mean for the lumbar curves sitting in the CC was -4.85 degrees, , with a range of -22.4 to 21.5 degrees. For the Nada-Chair, the mean lumbar curve was 4.71 degrees, with a range of -21.8 to 45.0 degrees (see Table 3). The difference between the mean lumbar curve in standing and the mean lumbar curve in the Nada-Chair was 41.99 degrees. The difference between the mean lumbar curve in standing and the mean lumbar curve in the CC was 51.55 degrees. The difference between the mean lumbar curve in the Nada-Chair and the mean lumbar curve in the CC was 9.56 degrees. The results of the chi-square analysis showed there was a significant difference between the number of subjects in extension in the Nada-Chair compared to the number of subjects in extension with the convention chair (see Table 4).

Table 1 One-Way Analysis of Variance for Repeated Measures Among the Means of the Lumbar Curves in the Three Positions

SOURCE	SS	DF	MS	F	P
BLOCKS/SUBJECTS	8523.265	29			
CURVE	45115.488	2	22557.744	213.984	<.001
ERROR	6114.238	58	105.418		
TOTAL	59752.991	89			

Table 2 Newman-Keuls Post-hoc Test

	Stand	Nada	CC
	46.70	4.71	-4.85
Stand 46.70	--	41.99*	51.55*
Nada 4.71	--	--	--
cc -4.85	--	9.56*	--

* p < .01

CV2 = 3.76 CV3 = 4.28

Table 3 Descriptive Statistics of the Lumbar Curves in the Three Positions.

	STAND	CONVENTIONAL CHAIR	NADA-CHAIR
# of Ss	30	30	30
Mean	46.70	-4.85	4.71
SD	12.71	11.00	14.90
SS	4683.85	3516.92	6436.74

Table 4 Chi-square Analysis for Frequency of Subjects with Flexion Versus Extension in the Nada-Chair and the Conventional Chair

	Flexion	Extension
Nada-Chair	12	18
Conventional Chair	22	8

CHI-SQUARE(1) = 5.498 p = .0182

CONTINGENCY COEFFICIENT = .290

DISCUSSION

The results of our study confirmed our first hypothesis that the curve produced with the Nada-Chair, as compared to the curve produced by the conventional chair (CC), was closer to the curve in standing. This was demonstrated by the fact that the mean curve in the Nada-Chair as compared to the mean curve in the CC, was 9.56 degrees closer to the mean curve in standing. It is apparent that the Nada-Chair produced more extension than the CC while the subjects were writing at a desk. Our second hypothesis was also confirmed. More subjects in the Nada-Chair exhibited extension than in the CC.

Our hypotheses were based on the extension theory which states that the optimal sitting posture is that which reestablishes the natural lordosis found while standing. (4,5,20) Although the Nada-Chair did not create as much extension as found in standing, it created more extension that the CC. Thus, the results of this study indicate that the use of the Nada-Chair while sitting at a desk promotes a better sitting posture by maintaining slight lumbar extension.

In today's society the majority of people spend an enormous amount of time sitting. As children, they are required to sit for many hours in class in chairs that do not provide lumbar support. As adults, many occupations and hobbies require sitting in the forward leaning posture. Often these life-long activities are performed in conventional chairs which promote poor sitting posture. This slumped posture has been associated with a high incidence of low back pain. (7) Devices such as the lumbar roll (8) and lumbar support (11,23) have been designed to maintain extension in sitting and prevent low back problems. However, the benefits of these devices are lost when working in the forward leaning position. The results of our study show that when sitting in the Nada-Chair, slight lumbar extension is maintained in the leaning forward position. Therefore, the use of the Nada-Chair, in both the work and school setting, may reduce the high incidence of low back pain by promoting good sitting posture. Other studies have found similiar results to our study. Several other chairs have been shown to increase the amount of lumbar extension. Keegan in his study found that a tilted seat that produced a thigh trunk angle of 135 degrees in sitting preserved the lumbar lordosis. (7) Bendix et al. found that the amount of lumbar lordosis increased with increasing forward inclination of the seat. They found an average increase of 1.4 degrees of lumbar extension per 5 degrees of seat inclination. (28) Based on this concept the Balans Multi-Chair (BMC) was designed with a forward seat slope of 20 degrees. Frey and Tecklin found that the BMC better approximated the natural standing lumbar curve in subjects writing at a desk than did the CC. In addition they found that the BMC created lumbar flexion less frequently than the CC (12). Anderson et al. found that when a lumbar support was used there was a significant increase in the total lumbar lordosis as compared to sitting without a lumbar support. (3)

One weakness in this study is that all of our subjects were physical therapy students who may have been familiar with the extension theory. During the study they may have tried to assume what they considered to be a correct posture; however, this may have affected both sitting positions equally. Another shortcoming of the study is that we did not test the Nada-Chair's ability to maintain the lordotic curve over a long period of time. Therefore, further research needs to be done in testing the ability of the Nada-Chair to maintain the lordotic curve during prolonged sitting. Other research needs to be done concerning: effects of the Nada-Chair on subjects with low back pain; the comfort of the Nada-Chair on the knees and lumbar area over time; EMG studies of the activity of the paraspinals and posture of the cervical and thoracic areas while sitting in the Nada-Chair.

This is the first study to investigate the effects of the Nada-Chair on lumbar curvature. We found that the Nada-Chair produced more extension than the CC did. Physical therapists can use the information from this study when considering the use of the Nada-Chair for their patients who require extension to prevent low back pain.

CONCLUSION

Our study showed that when sitting at a desk and writing, the Nada-Chair better approximated the standing lumbar curve than did the CC. Also our results showed that more subjects exhibited extension than flexion in the Nada-Chair than in the CC. This study supports the manufacturer's claim that the Nada-Chair promotes correct sitting posture. Although further research needs to be done, our study suggests that the Nada-Chair can be recommended by physical therapists when lumbar extension in sitting is indicated for the prevention of lower back pain.

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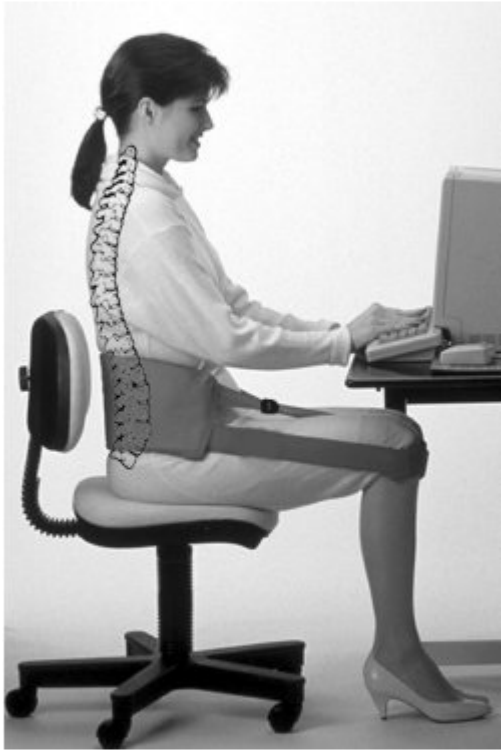
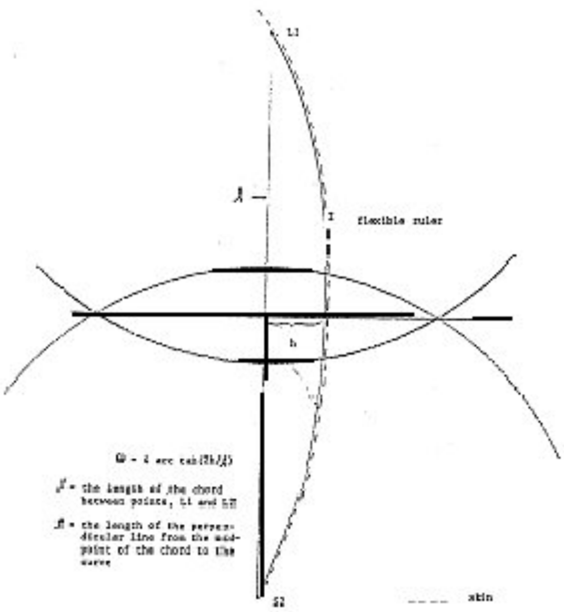


Figure 2-
Lumbar Curve Measurement with the Flexible Ruler



Raw Data of Lumbar Curve Measurements

Subject	Sex	Age	(lbs) wt	pressure	Curve Standing	Curve Sitting	Curve Z Nada Chair
#1	F	29	129	126 mm Hg	30° E	2.5° E	11.1° F
#2	F	24	126	136 mm Hg	47.1° E	11.8° E	19.7° E
#3	F	24	112	172 mm Hg	47.0° E	12.7° E	6.8° F
#4	M	22	171	159 mm Hg	27.8° F	17.2° F	11.3° F
#5	F	25	134	100 mm Hg	35.9° E	14.9° F	14.0° F
#6	F	23	119	110 mm Hg	52.2° E	12.7° E	8.1° E
#7	F	22	124	119 mm Hg	41.1° E	4.1° F	15.9° E
#8	F	29	122	136 mm Hg	52.1° F	6.1° F	18.2° E
#9	F	25	129	138 mm Hg	51.7° E	10.8° F	0° F
#10	F	28	93	94 mm Hg	49.9° E	11.7° E	9.9° E
#11	M	23	245	258 mm Hg	37° E	9.9° F	11.6° F
#12	F	23	141	138 mm Hg	54.5° E	4.5° F	2.3° F
#13	F	22	130	122 mm Hg	70° E	4.9° E	0° F
#14	F	22	125	112 mm Hg	53.4° E	21.2° F	11.9° F
#15	F	20	121	132 mm Hg	38.1° E	18.5° F	21.5° F
#16	F	39	120	124 mm Hg	57° E	3° F	11.2° F
#17	F	30	130	102 mm Hg	50° E	8.8° E	[illegible]
#18	M	24	196	204 mm Hg	20.5° E	22.4° E	14.9° F
#19	M	23	128	118 mm Hg	21.6° F	0° E	13.2° F
#20	M	24	156	162 mm Hg	47.1° E	19.5° E	3.0° F
#21	F	21	133	138 mm Hg	46.5° E	4.1° F	2.2° E
#22	F	24	119	106 mm Hg	69.6° E	21.5° E	9.1° E
#23	F	25	103	98 mm Hg	40.5° E	13.3° E	[illegible]
#24	F	21	131	124 mm Hg	54.0° E	6.9° F	30.9° E
#25	F	23	134	134 mm Hg	72°	2.5° F	7.3° F
#26	M	24	142	198 mm Hg	38.1° F	2.8° F	4.5° F
#27	F	42	135	199 mm Hg	64.2° E	13.6° F	20.3° E
#28	F	21	96	108 mm Hg	42.0 E	19.2° F	7.6° E
#29	F	32	179	196 mm Hg	42.4° E	22° F	9.5° E
#30	F	26	114	102 mm Hg	47.3° E	7.3° F	6.9° E