Spring 4-1997

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Dave Gregory
Old Dominion University

Recommended Citation

Gregory, Dave. "Changes in Spinal Height Supine and Walking in Subjects With and Without Lower Back Pain" (1997). Master of Science (MS), Thesis, Rehabilitation Sciences, Old Dominion University, DOI: 10.25777/7t5d-n282
https://digitalcommons.odu.edu/pt_etds/20

CHANGES IN SPINAL HEIGHT SUPINE AND WALKING IN SUBJECTS WITH AND WITHOUT LOWER BACK PAIN

by

Dave Gregory
B.S. August 1981, Old Dominion University

A Thesis submitted to the Faculty of
Old Dominion University in Partial
Fulfillment of the Requirement for the
Degree of

MASTER OF SCIENCE

PHYSICAL THERAPY

OLD DOMINION UNIVERSITY
APRIL, 1997

Approved by:

Dr. John L Echternach

Dr. George Maihafer

Professor Martha Walker

ABSTRACT

CHANGES IN SPINAL HEIGHT SUPINE AND WALKING IN SUBJECTS WITH AND WITHOUT LOWER BACK PAIN

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Dave Gregory

Old Dominion University, 1997

Purpose: The purpose of this study was to develop and test a device that could be used in clinical situations to measure spinal height in subjects with lower back pain.

Introduction: Spinal height measurement provides information on the impact of spinal loading on the intervertebral disc. The stadiometer is presently the most accurate device for this purpose but users of the device must be trained to be measured. This excludes untrainable subjects such as those with lower back pain. For this study, a new instrument was developed combining aspects of the stadiometer and other devices to produce a simpler method of measurement.

Methods: A sample of 40 subjects with lower back pain were compared to a group of 40 subjects without lower back pain. Five measurements were taken at 4 minute intervals while the subject was in a semi-Fowler's position. Three measurements were then taken at 4 minute intervals while the subject walked. Repeated measures ANOVA was used to assess differences between groups for position and time of measurement effects.

Results: No significant differences were found in spinal height between groups for any of the measurement intervals using the new instrument.

Conclusions: The measuring device, investigated in this study, demonstrated no differences in spinal height between subjects with and without lower back pain when supine and walking.

TABLE OF CONTENTS

LIST OF TABLES

TABLE

LIST OF GRAPHS

Many elaborate imaging and testing systems have been developed to test the performance of the spine. Each of these methods provide specific, but different information about the integrity of the intervertebral disc . Modern imaging techniques have achieved a result that is very similar to direct viewing of internal anatomy and pathology providing great detail. However, these approaches are static images and do not reveal changes in the structures with movement. Clinically, lower back pain from disc pathology temporarily decreases when the spine is perpendiculer to the force of gravity. Certain postures or positions increase symptoms. Frequent measurement of spinal height can provide information on dynamic changes in the spine in response to both instantaneous and cumulative loading.(1)

The purpose of this study is to compare changes in spinal height during relative unloading (decreasing the effects of gravity) between subjects with and without lower back pain. Unloading measurements give an indication of the imbibing properties of the intervertebral disc or its ability to regain height after a load is removed (in this case gravity).(1) Plots of the height measurements over a period of time might reveal differences between those with lower back pain and those without lower back pain. This could include both the magnitudes of mean spinal heights and/or different areas under a curve plotting a series of spinal height measurements over time. This would prove to be invaluable in assessing the recovery of individuals seen in the clinic with lower back pain, providing information on the spine's response to controlled forces.

There are several instruments to measure spinal height including computed tomography (CT) and magnetic resonance imaging (MRI). Since height changes of individual intervertebral units are slight, a high level of reliability and accuracy are required to avoid large variations both within and between subjects. Noninvasive and direct measurement devices have increased in accuracy but have required more subject training and skill in acquiring the reproducible measurement positions. This obstacle has prevented measurement of subjects with lower back pain, especially in a clinical situation. The next step in the research process is to include subjects with lower back pain in a study that is clinically based.

Literature Review

Dynamic properties of the intervertebral discs have probably been known for some time. Jazwinska found a source that recorded single subject changes in height over 200 years ago.(2) As stated by Kazarian, changes in spinal height for a group were first recorded in 1897 by Bencke.(3) Later in 1935 DePuky measured spinal height and found a two percent decrease in children and a .5 percent decrease in 70 year old subjects during the course of the day.(3) Armstrong first postulated that the mechanism for gain and loss of height was due to a change in the osmotic pressure in the discs with changes in load between activity and sleep.(3) Eklund and Corlett advanced the accuracy of height measurement with a device that was eventually called a stadiometer.(4) The apparatus consisted of a platform tilted ten degrees and a pillar extending perpendicular to accommodate the subjects height. Four rods extended from the pillar contacting the subject's sacrum, lumbar spine, thoracic spine, cervical spine, and occiput. Adjustment of these permitted reproduction of standing postures for repeated measurements. To control head posture, each subject wore glasses with lines on the frames which lined up with a line placed on a large mirror in front of the platform.

Actual measurements were taken from a round plate which had a diameter of 15 cms and contacted the subjects head. A rod extended from this plate through a transducer producing an accuracy to 1/10th mm. To maintain contact with the subject's head a pressure of 1-2 Newtons was required.(4) Since the equipment was so sensitive to postural changes, each subject had to be coached to maintain a comfortable erect posture. Weight scales were placed under each foot to check and maintain an even weight distribution and the feet were placed in 25 degrees of abduction. Subjects were instructed to fold their arms across their chest while maintaining contact with the posterior rods and "stretching to be a little taller". Shoulder elevation was used to control the amount of inhalation.(4)

Because of the complexity of attaining this position initially, Ecklund and Corlettt pretrained subjects for 20 minutes to obtain reproducible measurements. Fifteen normal subjects were used, five of whom were women.(4) The actual experimental procedure involved successive measurements taken before and after eight conditions with variable amounts of spinal loading. Many of the subjects participated in more than one condition. Rates of spinal shrinkage were then modeled using an exponential function, changing the constants with varying loads applied to the spine. Results of the studies showed a direct correlation between loss of spinal height and the magnitude of spinal loading. Descriptive statistics were given, such as the standard deviation, which was .628mm for all of the measurements taken, and no further statistical testing was reported. Rates of height loss and recovery also correlated with the magnitude of change in spinal loading, although recovery took place at a faster rate than height loss for all conditions.(4) Age, load characteristics, hours of sleep, and time of the day were mentioned by the authors as factors that need to be controlled to produce reliable measurements.

Other researchers have made modifications to the stadiometer. Tyrell attached microswitches to the support dowels at specific landmarks and altered the posterior tilt of the unit to five degrees.(5) Measurements were taken continuously to plot circadian variations. A second series of tests compared standing with a load, lifting, and rest in the Fowler's position compared to usual standing. Eight normal subjects were used for this study. Total circadian variation in stature was found to be 1.1%. Height measurements correlated with spinal loading and the study showed that recovery took place at a faster rate than did loss. When the subjects assumed the Fowler's position, recovery of spinal height occurred at an even faster rate. Recommendations for the application of these results include rest periods following intervals of high spinal loading for industrial workers.(5)

Since circadian variation in spinal height is associated with physiological events, one could postulate that there is a natural circadian variation in height regardless of the load. Sleep deprivation studies have refuted this as there is no restoration of height without lying down.(2) Speculation followed that sleep may have the added benefit of decreased muscle tone, permitting further gains in height. The mean circadian variation in height was 17mm from the greatest to least height(2) and comparable recoveries were made by subjects after loading when lying down without sleep.(4,5) No data is given on the average pre-measurement height of the subjects for comparisons with other studies. Time of day, time of performance and rest all influence spinal loading and height measurements.

Comparisons of spinal height have also been made between runners and non-runners. Measurements were taken after circuit weight training, a 6km run and 19km run.(6) It was postulated that the trained individuals would have less spinal height loss following these activities because of less exertion. The studies did not confirm this. Although there were some weak correlations between perceived exertion and height loss in untrained runners, overall no new interaction effects were found to correlate. Relationships were found between height losses and the distance ran or the amount of weights lifted.(6) A slightly lower height change was found in women who performed circuit weight training similar to the above two studies.(7) Since there was no correlation to vertebral body diameter, the intensity of the exercise protocol may have been less intense. Their circadian height change was 15.4mm or .92% of the total body height.(7) Rates of change were similar however due to the similar constant obtained to best fit the data. This supports Urban's theory on the similarity of stress-strain curves found between discs from thoracic and lumbar segments in in-vitro studies.(8) He stated that the proteoglycan to collagen ratio determines swelling pressure and not anatomical differences. The differences in response to stress that do exist between discs is due to the fact that their chemical make up places them on a different parts of the total stress-hydration curve.(8) Also similar to other studies, perceived exertion when performing the exercises was greater in the morning.(7) Stiffness from swelling in the discs may be contributing in combination with a number of other physiological factors. Another finding in this study supports data previously mentioned in in-vitro studies.(3) That is, height losses are smaller towards the end of the day when disc height has decreased.(7) Many studies have illustrated the curve or decreasing slope of height loss when a constant force is maintained over time.(2-5,9-17)

Data on height changes in microgravity have shown general increases of 5.5cms, which is much greater than the recovery in assuming Fowler's position or even traction.(16) There are muscular forces when performing tasks in space but creep (disc deformation) from compression is absent due to the lack of gravity and forces for all movement are reduced. Osmotic transport may also be enhanced in microgravity especially during periods of activity because of the increased metabolism and blood flow.(16) Apparently, gravitational forces are mainly responsible for producing height changes and intermittent spinal loading is constantly compounding it. When preparing spinal specimens for testing, nuclear enlargement was reported by experimenters when restrictions were removed such as muscles and the posterior elements. This again illustrates the balance that exists between the imbibing forces and loading forces which are constantly changing and superimposed on the constant force of gravity.

One author did include marathon runners with lower back pain as subjects. A stadiometer was used to test the effects of running and jumping on changes in spinal height and its possible relationship to pain. Boocock took repetitive measurements from normals before and after intervals of running on a treadmill.(18) The speed was varied for three different measurement sessions. Results showed a greater decrease in height with both increased speed and longer duration.(18) Comparisons were also made between subjects with a subjective history of lower back pain greater than once per month, for at least twelve months and a normal group. No significant differences were found between the two groups for spinal shrinkage, exertion and most importantly, pain.

If the runners with lower back pain did not experience significantly more pain during the run, then there may be nothing to distinguish between the two groups. In other words, pain may compromise the performance of the experimental group imparting greater loads on the spine. All of the subjects were marathon runners and testing did not approach the amount of cumulative loading that would take place during a marathon. In order for a test to discriminate between groups with and without lower back pain, it must load the spine to the point of pain that may discriminately influence the dependent variable, which is, in this case, height. Interval measurement may have revealed differences in how the two groups changed height.

The same authors measured a group of normals before and after drop jumping from a box 1 meter high. (19) Intervals of jumping lasted six minutes, followed by a continued measurement during an interval of rest. Rest was divided between groups that stood and those that were inverted in a gravity traction device. Losses in height averaged 1.7mm and recovery took place equally once both groups were standing for 30 minutes.(19) When compared to other studies using anti-gravity traction, height gains took place at a faster rate in a disc that was previously loaded.(19) This provides evidence that resistance to tension also increases with time and a constant traction force. Another study done by Bridger obtained greater height increases after traction when compared to lying in a semi-flexed position but did not compare recoveries.(20) Mean increased stature after traction was 8.94mm and after lying down in the same position, 1.15mm. So traction has the same effect for short intervals as microgravity does for long intervals acting opposite of load deformation and creep (slow deformation) from compression forces.

Important implications can be drawn from this. If there is no difference between trained and untrained subjects, then the disc may not respond to conditioning and or the subjects involved did not have discogenic symptoms. Height changes may be directly related to changes in the disc and, more specifically, a loss of fluid that are independent of the condition of the contractile elements. Secondly, if there is no training effect on the intervertebral discs, at least for neutral zone loading, training has no positive effect on the disc's ability to absorb forces. This may also explain why lower back pain occurs in populations with various levels of training or activity. Relative changes in force over time precipitate responses and outcome determined by the biomechanical and biochemical properties of the spine. A prolonged, low load force in just as detrimental as a short, high intensity force. All factors must be considered in the equation for it to be predictive. If humans lived in microgravity and were placed on the earth, the magnitude of the spines response would be just as severe. Training may not change immediate responses to forces but serve as a dampening effect for large fluctuations in forces. If neutral can be maintained with the application of a large force, the chances of injury are minimized long term effects would be reduced.(13) To sample the response of the spine to one force to predict its future response, increased accuracy was necessary to reduce standard deviations and error.

Further modifications were made to the stadiometer by Althoff et al who again measured normals after intervals of circuit weight training, vibration and an extended study involving different types of chairs.(17) The stadiometer angle was ten degrees with the basic structure remaining unchanged from previous studies. The advantages that were built into this stadiometer all contributed to subject feedback so that postural adjustments could be made without prompting by the experimenter. To reproduce the amount of pressure on the posterior probes that maintain spinal curves, microswitches were attached with connections to lights observable by the subject. Movement allowances were .5mm so that when contact was made one would light and if the probe was displaced more than .5mm, another light would indicate this movement. The subject could make adjustments in his posture accordingly. Control of head position was also displayed to the subject by a reflected laser beam from a mirror on their nose to a calibrated chart. The source of the laser was placed vertically above the nose. Tiltable contoured buttock supports, an adjustable head piece and back support were the other contact points as the subject was measured.

Because of the unacceptable error in measuring from the top of the head, Althoff placed a skin marker approximately 1.5 cms above the C7 spinous process. This area of skin was found to deviate the least with changes in cervical lordosis. To accurately measure the skin marker, a camera with cross hairs was mounted on a plate that was adjustable on a vertical support extending from the base of the unit. Measuring spinal height then entailed lining up the cross hairs with the skin marker. A linear transducer was interfaced with a computer along with the microswitches to calculate changes in height.

To eliminate the influence of preloading or variance in activity between subjects, a series of measurements were taken during a pre-test and fit to an exponential curve based on the three parameter formula mentioned earlier. This pre-test was terminated when a series of three measurements varied from the predicted values by less than a tenth of a millimeter. Thirty minutes was the average time for the pre-test and then loading tests were performed with weights from 0-30kgms in 5 lb increments. Measurements for each weight were done at separate sessions. Results were as expected; the height decrease correlated directly with the amount of the load and between subjects with the calculated cross-sectional area of the disc. (This was estimated by taking a number of anthropometric measurements such as wrist circumference.) Subjects with lower estimated cross-sectional area had greater losses in height.(17)

A second series of measurements were done after pre-tests with different frequencies of vibration combined with acceleration in the sitting position. In all cases, stature increased without significant differences between frequencies or sitting without vibration.(17) This surprising finding prompted Althoff to expand his study further to include a third test on different types of chairs. Again a pre-test was done followed by 30 minutes of sitting in 4 different chairs under two conditions. To control for the possible effects of heel pad swelling, measurements were also taken from a malleolar landmark and corrections were made to the data based on these findings. Chairs that unloaded the feet completely, such as the Balans required a greater correction for heel pad swelling. Even after the corrections for heel pad swelling, all of the chairs produced increases in stature that can only be interpreted as a decrease in spinal load or compression. Slumped sitting in an office chair with a 30 degree inclined back support produced significantly more stature increases than the other chairs. This is in contradiction to the in-vitro flexion studies,(12,13,21) Nachemson's in-vivo disc pressure measurements(22) and many preponderance of evidence, both clinical and experimental, cannot be refuted by one study on ten normal subjects, even though the technique is scientifically sound. It does seem, however that the proportional differences between the chairs even though not significant were in agreement with previous studies, implying that the obtained baseline may have skewed the data .

Because of the correlation to spinal load, there are several applications for this measurement method.(4) Evaluation of ergonomics, assessment of daily spinal stress for many types of populations would be a general usage. Specifically, spinal height measurements could be used to assess the healing response of a disc post injury or other types of spinal injuries. Devices mentioned up to this point have been accurate but too restrictive. They require postures that a population with lower back pain may not be able to maintain or reproduce. This is precisely the population that needs to be tested.

The stadiometer has the most potential for clinical use, being simple, inexpensive and the most accurate device to measure body height. However one imortant factor prevents this. Extensive subject training time is required to obtain a baseline. For subjects with lower back pain, the time required to obtain a baseline may increase due to complaints of pain or frustration from repeating measurements. Results of subsequent testing could be skewed because of poor cooperation or a faulty baseline. Heel pad swelling skews data when height measurements are taken after unloading.(17)

To include more rapid cycles of disc height change, Krag attempted to reproduce former circadian studies with a new measurement device.(16) He took measurements at smaller intervals using callipers in the supine position, with a plaster mold fit into the mattress to maintain spinal contours.(16) Standard deviation for repeated measurements was 1.98mm with a mean loss of height at 16.39mm or .9% for circadian measurements. Overall losses were comparable to other studies but two rates of height gain were obtained. Initial rapid gains more closely fit data obtained from microgravity studies but the rest of the height gain rate fit the Kelvin unit model ($h(t) = k(e -lt - 1)$. The author attributed this to measurement error and high standard deviations relative to the mean magnitude of measurements. Despite plaster molds to prevent height changes from variation in saggital spinal curves, measurement errors did occur, and, were related to subject positioning. Mean standard deviations for only calliper repositioning were .74mm and for subject repositioning 1.98mm.(16) Many difficulties would be encountered when applying this method to a population with lower back pain. One would be just the difficulty in assuming the supine position with the hips in neutral and knees flexed to 90 degrees. It was not mentioned in the study how the hip flexion angle was controlled and there was little control over rotation which may be a factor in larger subjects. Bony landmarks are difficult to reproduce between measurement times, raters and subjects. It did however, eliminate the need to control for heel pad compression when standing after lying down.

Other devices have been used to measure spinal height after sitting and vibration.(25,26) One study incorporated a cast to stabilize the spine, a vernier ruler and a magnifying glass to directly measure height from the top of the subject's head.(25) The mean standard deviation of an average of 5 readings was .74mm but results after vibration were highly variable and inconclusive.(25) There was a good reliability but what they might have been measuring is the ability of the subject to replicate a certain posture instead of a posture that was a result of vibration. Seated postures may also show a lot of variability.(26) Measurements were taken with a square mounted to an upright meter stick which was attached to a vibrating chair. No attempt was made to control sagittal posture except by verbal commands for the subject to be as tall as possible. Here, standard deviations for daily height measurements were minimal in the morning but became larger for later times. The authors dismiss saggital curves as a contributing factor since pre-tests were reliable. Time between measurements may have been a large factor since it would be easier for the subject to reproduce a posture without interrupting movements or events. Fatigue may also play a role in postural sway at the end of the day. Despite these drawbacks, a relatively high level of precision was obtained with a simple device and without extensive subject training. Some of the variability could be controlled with the use of probes as are on the stadiometer limiting saggital movement.

The most passive non-invasive method of measuring spinal height is stereophotography.(27) As the name implies, simultaneous photographs are taken of a subject facing a wall. To mark the skin, OP-SITE is used which is thin, transparent and adheres well to the skin, necessitating only one application. This improves the reliability of the measurement protocol. Photographs are analyzed using a stereoplotter which is presumably close to a digitizer. A study using this method did not include details of the actual measurement method but they did try to establish criterion related validity by comparing the photographic images with actual measurements. Height was measured by placing a mark on the wall with a carpenter's square, on the top of the subject's head, and from ear pinnae as the top points and the floor as the bottom point. Comparisons were made between actual and stereophotographic measurements for circadian variations. Comparisons were also made to delineate which areas contributed the most to this height change as the markers were placed in different areas of the spine. Forty percent of the gain found in the morning came from the lumbar area with an average increase of 8mm. No change was found in the saggital position of thoracic or lumbar curvature between morning and evening measurements.(27)

These findings are acceptable results considering the low number of subjects(12) and the unnatural position of measurement. Subjects were reqired to stand with their nose and toes touching a wall and their knees locked. Advantages to this method are that it is non-invasive, passive, and requires little or no subject training. Disadvantages include questionable reliability, and probable error between repeated sessions for the same subject due to variable skin marker placement. Reliability is questionable because of the 4 mm difference between the stereophotographic and direct measurements means, even though statistical testing showed no significant differences at the .05 level. With such a great difference between means, one would have to question how they can use differences of 1 mm to distinguish changes between two areas of the spine.

Tape measures have also been used to measure spinal height. Three studies were done on normal males who were runners to assess the effect of running on spinal height.(28,29,30) Subjects were prompted to stand next to a plumb line that bisected the lateral arm and thigh. One study used anatomical landmarks such as the calcaneocuboid joint, greater trochanter, acromion process and the temporomandibular joint.(28) Head angle was controlled by prompting the subject to gaze at a marker places on a wall in front of him. It is interesting that all of the studies used slightly different landmarks from C7-T1 for the top mark and S1-2 for the bottom. Two of the studies document Intraclass Correlation Coefficients between .97 and .99 and concluded that the measurement method was reliable.(29,30) Presumably because of the time between measurements and number of subjects, experimenters did not blind themselves to each measurement. A baseline was obtained in the morning to control for some of the effects of pre-loading(28) but they did not try to control or subtract normal height losses that would take place over the run interval. Even though these losses would be minimal, they would tend to decrease the difference between the pre-run and post-run spinal height changes.

The independent variable in these studies was a 7-9 mile run over a flat cross-country course. All of the studies were performed in the afternoon and measurements were taken immediately before and after running. They did not mention possible delays between the time subjects finished the run and the time of measurement. Analysis of means was done by t tests with all of the studies finding significant differences between pre-run and post-run measurements. Further division of data found no differences between young and older runners. For comparisons between groups of subjects of sufficient size (>30), the tape measure provides enough accuracy and reliability but for individual differences, standard deviations of .5mm or greater are not accurate enough.

Magnetic Resonance Imaging has also been used in attempts to answer dynamic properties of the disc under a load. Besides accurately measuring spinal height, a recent study was designed to determine the exact source (part of the disc) responsible for circadian height changes.(31) Eight normal young adult males were supine six hours before undergoing an MRI scan. Slices of 2mm were taken of a localized field of 2.5 cms centered on the L4 vertebral body. At least one week later, the same subjects were instructed to wake up at 7:00 am and spend 4 hours standing and 3 hours sitting. Through a detailed process and the use of computer software, three dimensional images were constructed of L3-S1 discs. The authors were blinded to the reconstructions so as to eliminate any bias. In reconstructing these images they were then able to manipulate them to obtain any three dimensional view or slice. Measurements were then taken of the anterior-posterior and lateral diameters, volume and height of the discs. Comparisons were then made between the images obtained in the evening after standing and sitting with those obtained after lying supine.

Results are listed as percentages and all parameters decreased in the evening measurements. Total volume decreased by 16.2%; height by 11.1%; and anterior-posterior diameter 6.0%. No significant difference was found for all of the lateral diameters. Three conclusions are then drawn from these results. First, most of the volume loss is accounted for by decreases in height and not radial bulging. Second, the three lower lumbar discs change in height by similar amounts. Third, changes are similar for subjects with similar morphological characteristics.(31) Subject positioning may unload the spine to the extent that radial bulging would be negligible, or reversing, especially given the time for set-up and imaging. No mention was made of endplate bulging, as done by in-vitro studies(32) which would interact with all of the dimensions of the disc. Possibly they thought it to be non-contributory because of the spinal unloading during the scans. Contrasts are also noted with the previous MRI study which obtained highly variable results in diurnal bulging and height changes.(33)

Variability in this study was minimized by using the same process for volume measurements of each reconstructed image and recording changes instead of actual calculations. One contributor might be the criteria that is set up to reconstruct different tissues and how well it coincides with anatomical divisions or transitions which are themselves not always discrete.

Ultrasound imaging has also been used to measure changes in disc height, as it was considered for use aboard the space shuttle along with the stereophotography mentioned earlier. An unpublished article revealed diurnal changes in spinal height as measured from the tips of transverse processes from L1 to L4. This average for seven subjects was 5.3mm which is in agreement with MRI studies that have confined their measurements to the lumbar area.(34) An attempt was made by this author to use ultrasound imaging in the same way, on a loaded spine to assess changes in height over relatively short periods of time. Several difficulties arose which limited the feasibility of continuing the study. These included resolution of the edges of the transverse processes, obtaining both transverse processes in one image or plane and measurement accuracies on the screen to only the millimeter level. Many, if not all of these may be overcome using a newer ultrasound imaging unit but this was not available. If the positions of imaging can be varied and the time it takes for measurement is low, it could provide information on individual vertebral unit responses to loads. Because it is noninvasive, safe and instantaneous, multiple planes can be obtained to clarify tissue boundaries. One drawback would be cost and training for clinicians to use the equipment.

CT scanning with discograms have also been used to compare disc height as it correlates with pain and disc degeneration. Logically, if the amount of disc degeneration correlates with pain and spinal height there should also be a correlation between spinal height and pain. This was the objective of the study involving 107 patients with lower back pain.(35) Basically, the criteria for subjects was an indication for discography with plain radiographs taken, not greater than eighteen months, prior to the discogram. To further classify the possible pain response upon injection of the contrast material, four categories were used depending on presence of pain and its similarity to "the" pain the patient was experiencing. For correlation to this, the discograms were also categorized according to an established scale that grades disc degeneration and annular disruption. Disc heights were measured from lateral radiographs and comparisons were made between the L3-4 level and L4-S1 levels. As in previous studies cited by the article, disc height did correlate significantly with levels of disc degeneration and disc degeneration correlated with pain. In contrast to previous studies, most of the disc height categories did not correlate with pain categories. There was a statistically significant difference in height for the exact reproduction group compared with the painless group. So not only does static disc height correlate with loading, short and long term, there also is a correlation with discogenic pain.

Even though this study involved static disc height without loading or unloading, it is relevant because of its inclusion of subjects with pain. General losses of disc height would place the disc in a constant trough of diurnal height changes and influence its potential to imbibe fluid against counteracting forces such as gravity, soft tissue and muscular contractions. Therefore, measurement of changes in disc height should correlate more strongly with pain.

Up to this point, little non-invasive research has involved subjects with significant disc pathology or lower back pain in general. Restrictions in the methods required for high levels of accuracy during measurements have excluded many types of patients that would be seen in a physical therapy clinic. Perhaps the device should be chosen because these types of subjects could be included. The highest accuracy for a simple measuring device came from the measuring square at 1.4mm. This number may be improved by including probes to stabilize saggital spinal curvature.

According to in-vitro trauma studies, the most sensitive measurement to traumatic injury in the lower back is a change in the neutral zone.(36) Variation should also occur in spinal height as it has a great influence on neutral zone movement through changes in the axis of rotation. Patients with lower back pain from traumatic onset should display variations in creep, load deflection and recovery due to the inflammation of the overlying soft tissue and possibly disc pathology.(37) Perhaps the most important response of interest to a physical therapist in the initial stages of recovery would be recovery from creep or load deflection. Commonly, reports of pain coincide with the extremes of height, in the morning and evening. Since there is no correlation between pain and static height, dynamic height may present a better picture. A test that permits quicker measurements with reliable accuracy may reveal differences in plots of height changes between subjects.

Some of the clinical uses of spinal height could be comparing measurements before and after treatment to assess relative spinal loading or unloading. Correlations could be made with subjective findings for compliance to programs at home. Adjustments could be made to each patients. treatment, based on more objective data. Changes in height could be compared rather than static height measurements for variation in response to healing or progression of the injury if the disc is involved.

Hypothesis: Subjects with lower back pain will have a different magnitude of mean height changes during and after spinal unloading than the control group.

Null Hypothesis: There will be no difference in the mean magnitude of height measurements between a control group and those with lower back pain during and after spinal unloading.

METHODS

Subjects

A sample of convenience was used for both the control and experimental groups. 40 normal subjects without a history of lower back pain between the ages of twenty and sixty comprised the control group. The majority of the experimental group was made up of patients referred to Peninsula Physical Therapy for lower back pain and others were from the local community. Patients with cervical spine problems were excluded because of the difficulty in reproducing head positions. For the purposes of this study, the experimetal group was defined by subjects reporting episodes of lower back pain occurring at least on a weekly basis. Relevant histories were recorded for possible correlation to the outcomes. These included previous surgery, history of lower back pain and type of onset. Subjects diagnosed with scoliosis were excluded due to the possibility of a characteristic response to spinal unloading. Subjects participated on a voluntary basis and signed a consent form prior to their participation.(appendix B)

Equipment

An apparatus was constructed using white masonite over 2 x 4's to form a platform for sitting.(Figure 1) A stool was constructed so that the height could be set at 2.25, 4.25, 6.25 inches from the floor. Angled steel was attached perpendicularly to the posterior aspect of the chair to support the measuring arm and reference square and was adjustable to two different heights. This allowed for extremes in subject height. Probes consisted of .5 inch carriage bolts that were threaded through holes in the angled steel. The lateral thoracic supports were made from vertical 2 x 4 s attached to horizontal pieces of angled steel and could be adjusted vertically. A Zircon electronic level was attached by velcro to safety glasses to control head position. A smaller carpenter's square was fastened to the vertical support with a C clamp for the reference point. Callipers accurate to .001 inches were used to measure from the measurement arm to the reference arm. For resting intervals, standard plinths and couches were used. There was no set path or distance walked between the walking measurement intervals.

A reliability study was done prior to the experimental measurements since the measuring device was novel. Ten subjects were measured repeatedly 10 times consecutively. Graph 1 shows the standard deviations with a mean of .06 inches or 1.52

mm. These measurements were acceptable for the purposes of this preliminary study to assess the feasibility of a clinically based spinal measurement test.

Procedure

To standardize pre-loading, subjects were tested between 9 to 12 hours after waking and walked for 5 minutes immediately prior to measurement. Each subject was interviewed for specific data including wrist circumference, height, weight, age and history of lower back pain. Wrist circumferences were taken because of their correlation with vertebral body diameter and possible contribution to differences found between the two groups.(38) To standardize postures for repeated measurements, probes were set at the C6, and L4 spinous processes while the subject was in a comfortable sitting posture. A more lateral support was positioned just below the inferior angle of each scapula and a stool was placed in front of the chair to position the thighs parallel to the chair. Paper on top of the stool permitted tracing the outline of the feet. An outline was also traced around the buttocks to control lateral shifting when repositioning for each measurement. Safety glasses were then put on and an electronic level was attached with the head in a neutral position that was comfortable for the subject.

Measurements were then taken by lowering the measurement arm to the subjects head so that it remained perpendicular to the upright while the subject maintained the constant beeping sound that indicated the level had returned to the measuring position. A knob tightened against the upright marking the subject's spinal height. Callipers were used for the actual measurement between the reference square higher on the upright and the measurement arm. This blinded the experimenter to the actual measurements because the scale on the upright was not used or observed. The measurement arm was then loosened between each measurement. After the initial measurement, subjects positioned themselves according to the outlines on the stool and seat, while the experimenter provided cues to correctly align with the probes. The subject again was required to reproduce a neutral head position by listening for the beep from the electronic level. Subjects walked between all of the measurements except the ones during spinal unloading. Here they assumed roughly the Fowler's position or supine with their knees elevated. The four minute intervals between the measurements did not include the time for each measurement which was roughly 40-60 seconds.

A baseline measurement was obtained by averaging three consecutive measurements that varied by less than .05 inches. Subjects stood up briefly between these measurements and then realigned themselves according to visual, verbal and auditory feedback. For both groups, five measurements were taken while supine and three while walking. For the first 5 measurements, subjects were lying supine with their knees flexed. After 4,8,12 and 16 minutes, they transferred to the measurement chair to be measured. Between the last three measurement intervals, subjects walked at a slow to moderate pace and measurements were repeated at 4,8, and 12 minutes.

Data Analysis

Means and standard deviations (SD) were calculated for each interval and displayed according to group. Histograms and Mauchly's test were done to determine the type of ANOVA test that was appropriate for the amount of variance in the data. A total of 5 univariate one factor repeated measures ANOVA tests were run comparing time of measurement with group, and with position, supine or walking. Four tests were done comparing different segments of time intervals for each group and one test included all time intervals for both groups. For example, the first three measurements taken after the supine position, were compared with the three measurements taken after walking. Then the last three measurements at twelve, sixteen and twenty minutes were compared with the walking measurements. For both groups, three sets of intervals were compared, which included a zero baseline measurements for all subjects. Bonferroni confidence intervals were done to show the individual intervals responsible for significant F values.

RESULTS

Anthropometric data was recorded at the time of measurement and is compiled in Table 1. Further details were recorded regarding the frequency and chronicity of lower back pain but a secondary statistical analysis to assess their contribution to the results were unnecessary.(appendix C)

Histograms were done for each measurement interval. Analysis of the histograms, showing the dispersion around the mean for each interval, showed that some of the intervals were bimodal or skewed, mainly to the left, but a majority were normally distributed

Graphs 2,3 show the means and standard deviations for each interval and group. These show a general gain in height while subjects were supine, increasing further during the walking intervals. At the twelve minute walking interval, the no lower back pain group showed an incomplete return to baseline while the lower back pain group continued to gain height. In general, the magnitude of the mean height changes were decreased for the lower back pain group. For all of the intervals, the standard deviations were larger than the mean height changes recorded for all of the time intervals. They were even larger than the range of mean height changes for all of the time intervals for both groups.

There were no interval means found to be significantly different in the ANOVA tests for the lower back pain group as illustrated under the significance of F in tables 2,3. For the group with no lower back pain, comparing the 4,8,12 minute intervals, the position by time effect was significant with an F value of .006.(Table 4) Comparing the last three intervals in supine with the walking intervals produced an F value of .055.(Table 5) For both groups in the three position, three time interval comparisons, no means were found to be significantly different.(Table 6) As graph 2 shows, the mean height change gradually increases as the time in the supine position increases, so the differences between the later supine measurements and the walking ones were less. The paired sample Bonferroni confidence intervals did not reveal any pairs without zero, so no intervals were significantly different. Table 7 shows these paired confidence intervals.

Discussion

The null hypothesis was accepted, which stated that there were no differences in mean height changes, from supine to walking between subjects with and without lower back pain.

In looking at the group characteristics in table 1, it is interesting that the mean wrist diameters do not correlate with the distribution of males and females. Wrist circumference correlates with intervertebral body diameter(38) and males generally have larger bone structure. The weight and wrist diameter are also inversely dissimilar.
Mean group ages are fairly close considering that this was a sample of convenience.

For statistical testing, it was felt that the sample size was large enough to offset the criterion for multivariate normalcy within intervals. Since the p value for Mauchly's test was greater than alpha, the variance-covariance assumptions were satisfied for the univariate one-factor repeated measures ANOVA test. Seperate tests were run on each group to confirm the findings of the combined test and also to isolate intragroup variability that might have contributed to the results.

Results from this study show the neccessity of maximizing every aspect of the procedure to ensure the greatest possible changes in the dependent variable. Since the magnitude of height changes is small, standard deviations must be kept low to achieve any type of statistical significance between short measurement intervals. Studies involving tape measurement achieved SDs of 2.5 - 5mm.(28,29) Comparisons were made before and after certain activities which involved a larger magnitude of height change compared to the SD. Most of the SDs for the stadiometers were well under 1 mm(3-7,16,19,20) with the exception of Garbutt's study which ranged from 1.9mm to 3.69mm.(18) These were taken after running which is more variable between subjects. Preliminary SDs in Garbutt's study were at .5mm after extensive subject training. He also noted exclusion of subjects with chronic lower back pain because of their poor tolerance to training and inability to achieve low SDs. Sullivan's (26) study which used a simple square obtained SDs of 3.2 mm which is similar to this study at 2.5 - 3.0mm. Krag used a body calliper method supine and obtained SDs of .74 for calliper repositioning and 1.98mm for total body repositioning.(16) Another study done with a square achieved SDs of .74mm but encountered a tremendous amount of intersubject variability. (25) They attributed these results not to measurement error, but pre-existing conditions, such as preloading or degenerative disc disease. Measurement error cannot be excluded here due to the high intersubject standard deviations.

The closest study to this one in design and statistical testing was done by Bridger et al.(20) Height changes after traction were compared with crook lying. Measurements were taken at 5 minute intervals for 5 subjects. Effects of traction and time of measurement were found to be significant, along with differences between subjects. Here the SDs were high and the sample size was small but the mean magnitudes of height changes were proportionally greater. Experimental design may be contributing to the variability here. It is important to maximize the mean height changes through the application of forces or measurement through greater time intervals while instrumentation and sampling allow proportionally small enough SDs. One way to decrease variability within subjects is to decrease subject repositioning between measurements. It was found that repositioning the calliper only produced decreased SDs because of the reduction in lower vertebral postural adjustments. If applied to the experimental procedure, this would greatly limit the number of applicable independent variables. Maximizing bony contact of the measuring instrument should minimize postural adjustments that may contribute to variance.

Rates of mean height changes in other studies for the same time interval and forces on the spine measured here are also comparable.(16) Mean interval height changes range from .24 - 1.8mm for 20 minutes in the supine position for both groups. This rate of change is similar to what other authors obtained with stadiometer measurements.(16,17,19,20) In Tyrell's study with stadiometer measurements, recovery from loads beyond baseline were indicated by height gains of 1 mm in 5 minutes.(5) At this point in the recovery line became curvilinear and so extrapolations may agree with the present study. Fowler's position, which was used in Tyrell's study may unload the spine to a greater degree than the supine with knees bent position used in the present study.(5) Krag, using body callipers supine, also obtained comparable gains in height at ~2mm for 20 minutes.(16) Bridger, using a stadiometer, obtained height gains of 3mm after 20 minutes in the Fowler's position.(20) Individual measurements were highly variable but, as stated above, the ratio of standard deviation to mean height changes must be low before significant differences can be obtained.

Graph 4 shows a comparison of standard deviations for all noninvasive measuring devices The device in this study is labelled the T chair and is last on the X axis. Higher SDs were obtained for some of the stadiometer studies but since they were spinal loading studies, the height changes were proportionally greater.(6,7) In other words, the actual changes in height from testing, were larger than the SDs.

Several factors contributed to the high intersubject variability. It is difficult to standardize preloading for a large group of subjects. Their activity level previous to the measurement and the time of measurement both varied between subjects. There is an ideal time period to establish a baseline, depending on the accuracy of the instrument and relative amount of preloading. If the baseline is established in a short time period, height changes may still be taking place and adjustments to reach equilibrium would be included in the experimental measurements. This was illustrated by some subjects who gained height throughout the entire experiment. On the other hand, if obtaining baseline takes too long, normal circadian variations in height may be taking place.

Instrumentation also contributes to the large standard deviations. A certain amount of judgment was necessary for the subjects to position their buttocks on the bench repeatedly in the same position. Clothing was disturbed as they changed positions from supine to sitting producing slightly different profiles to line up with the tracing on the bench. Head position was controlled in the transverse plane by lining up the measurement arm with the center of the head. For subjects with little hair, the arm could be placed consistently with little difficulty, but for subjects with a lot of hair, more estimation took place. The glasses that the electronic level was attached to also may have moved slightly as subjects changed positions, producing slightly varied angles of saggital plane position during measurements. To a smaller degree, the pressure of the measurement arm on the head was not calibrated. Error and variability was involved in each subject's ability to reproduce measurement arm pressure and position and relay that to the experimenter. Adjustments might have been subconsciously made in posture to correct for initial over or under pressure when the measurement arm was initially lowered. As mentioned earlier, voluntary changes in spinal curvature can account for 2-3 cms in height changes.(16,20) Standard deviations were high in comparison to the means but much lower than the range of height changes subjects could achieve by adjusting spinal curvature. In other words, there was some control in the measurement method allowing subjects with lower back pain to participate without significant guarding but not enough to discriminate between subjects as a group or individually.

Suggestions for improvement revert back to the stadiometer. Measuring in the sitting position eliminates the effects of heal pad swelling(17)but there seems to be more variance in postural curves or a greater neutral zone for sitting. Its accuracy is neccessary to minimize variance between measurements between and within groups. To compensate for the weaknesses outlined above and use the same device, measurements and independent variables would have to be done without subject repositioning. Using only calliper readjustment between measurements, variance from repositioning and standard deviations would be reduced. To maximize spinal height change, loading should be done in the morning and unloading in the evening. This would put greater relative force on the spine, and height changes would be recorded in the steeper part of the curve for both creep and load deflection.

Another method of measurement could be employed once an instrument is found to be highly reliable across a wide population. Instead of standardizing the relative load on the spine, the creep or deflection curve could be standardized and the relative load recorded. This could be normalized according to vertebral cross-sectional area through wrist diameter. This would acknowledge the many levels of variability present in the intervertebral disc and serve to rate each subject's response to the load. Clincal correlation could then determine proper lifting limits to avoid injury to the disc.

There may be a set point of spinal stress tolerance determined by genetics and activity during growth. When this point is passed, pathology develops that is irreversible. Disc dessication is part of the aging process.(30) To maximize resistance to injury, conditioning is neccessary during the growth years and spinal protection during the second through fourth decades when the risk of disc injury is highest.

Another explanation for the results may be that spinal height is not a constant even for small increments of time. It may naturally fluctuate around a mean, varying with respiration and postural adjustments. In order to truly capture these changes along with changes in height over more extended periods of time, constant monitoring would be neccessary. Technology may provide some type of device that would constantly monitor spinal height and relay those numbers to a computer through telemetry.

Ultrasound imaging may also be applied since modern machines have better resolution and the accuracy of measurements improves. Like MRIs and CT scans it would differentiate between individual spinal levels but at a lower cost.

Conclusions:

Spinal height is a valid measure of spinal stress of many types, with the least amount of active participation required by the subjects. The measurement device used in this study permitted the inclusion of subjects with lower back pain, but due to the nature of the independent variables, mean height changes were not proportionally greater than intersubject standard deviations. No significant differences in spinal height were found between a group of subjects with and without lower back pain after lying supine and then walking.

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TABLE 1

GROUP CHARACTERISTICS AND COMPOSITION

	Mean Age	Weight (lbs)	Mean time of measurement	Wrist diameter (inches)	Females	Males
control group	33.9	159	2:40PM	2.15	30	10
experimetal group	35.9	182	2:50PM	2.04	15	25

Table 1 shows anthropometric characteristics of the subjects.

TABLE 2

Comparisons of time and position of measurement.
LOWER BACK PAIN GROUP
SUPINE 4, 8, 12 MINS
WALK 4, 8, 12 MINS
(TOM indicates time of measurement.)

```
* * * * * * A n a l y s i s   o f   V a r i a n c e -- design   1 * * * * * *

Tests involving 'TOM' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation         SS     DF      MS        F  Sig of F

 WITHIN+RESIDUAL            .38     78     .00
 TOM                        .03      2     .01     2.75     .070

 Observed Power at the .0500 Level
 Source of Variation   Noncentrality   Power

 TOM                       5.497        .527
________________________________________________________________
Tests involving 'POSITION BY TOM' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation         SS     DF      MS        F  Sig of F

 WITHIN+RESIDUAL            .29     78     .00
 POSITION BY TOM            .01      2     .00      .91     .405

 Observed Power at the .0500 Level
 Source of Variation        Noncentrality   Power
 POSITION BY TOM                1.827        .202
```

(F values are greater than the alpha level showing nonsignificance between means of measurements.)

TABLE 3
Comparisons of time and position of measurement.
LOWER BACK PAIN GROUP
SUPINE 12, 16, 20 MINS
WALK 4, 8, 12 MINS
(TOM indicates time of measurement)

```
******Analysis of Variance--design 1******

Tests involving 'TOM' Within-Subject Effect.

AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
Source of Variation        SS     DF      MS        F  Sig of F

WITHIN+RESIDUAL           .30     78     .00
TOM                       .00      2     .00      .63     .536
Observed Power at the .0500 Level
                      Noncen-
Source of Variation   trality      Power

TOM                   1.256        .153
____________________________________________________

Tests involving 'POSITION BY TOM' Within-Subject Effect.

AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
Source of Variation        SS     DF      MS        F  Sig of F

WITHIN+RESIDUAL           .40     78     .01
POSITION BY TOM           .00      2     .00      .39     .679
Observed Power at the .0500 Level
                          Noncen-
Source of Variation       trality        Power
POSITION BY TOM            .778          .114
```

(F values are greater than the alpha level showing nonsignificance between the means of measurements.)

TABLE 4
Comparisons of time and position of measurement.
NO LOWER BACK PAIN GROUP
SUPINE 4, 8, 12 MINS
WALK 4, 8, 12 MINS
(TOM indicates time of measurement)

```
* * * * * * Analysis of Variance -- design 1 * * * * * *

Tests involving 'TOM' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation          SS     DF      MS        F  Sig of F

 WITHIN+RESIDUAL            .38     78     .00
 TOM                        .00      2     .00      .09     .915*
 Observed Power at the .0500 Level
                          Noncen-
 Source of Variation      trality     Power

 TOM                        .177       .065

Tests involving 'POSITION BY TOM' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation          SS     DF      MS        F  Sig of F

 WITHIN+RESIDUAL            .52     78     .01
 POSITION BY TOM            .07      2     .04     5.54     .006**
 Observed Power at the .0500 Level
                          Noncen-
 Source of Variation      trality      Power

       POSITION BY TOM     11.075       .840
```

*(F value is greater than the alpha level showing nonsignificance between means of measurements.)

**(F value is less than the alpha level showing significance between means of measurements between supine and walking.)

TABLE 5
Comparisons of time and position of measurement.
NO LOWER BACK PAIN GROUP
SUPINE 12, 16, 20 MINS
WALK 4, 8, 12 MINS
(TOM indicates time of measurement)

```
* * * * * * A n a l y s i s   o f   V a r i a n c e -- design  1 * * * * * *

Tests involving 'TOM' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation          SS     DF       MS         F  Sig of F

 WITHIN+RESIDUAL       .49     78      .01
 TOM                    .01      2      .00      .57     .566
 Observed Power at the .0500 Level
                       Noncen-
 Source of Variation   trality        Power

 TOM                   1.146         .144
_____________________________________________________________________
Tests involving 'POSITION BY TOM' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation          SS     DF       MS         F  Sig of F

 WITHIN+RESIDUAL       .37     78      .00
 POSITION BY TOM      .03      2     .01     3.02     .055
 Observed Power at the .0500 Level
                            Noncen-
 Source of Variation          trality   Power

       POSITION BY TOM         6.040    .569
```

(F value is greater than the alpha level showing nonsignificance between means of measurements.)

TABLE 6
Comparisons of time and position of measurement.
BOTH GROUPS (three way ANOVA,TOM indicates time of measurement)
SUPINE 0, 4, 8 MINS,SUPINE 12,16,20 MINS, WALK 4,8,12 MINS

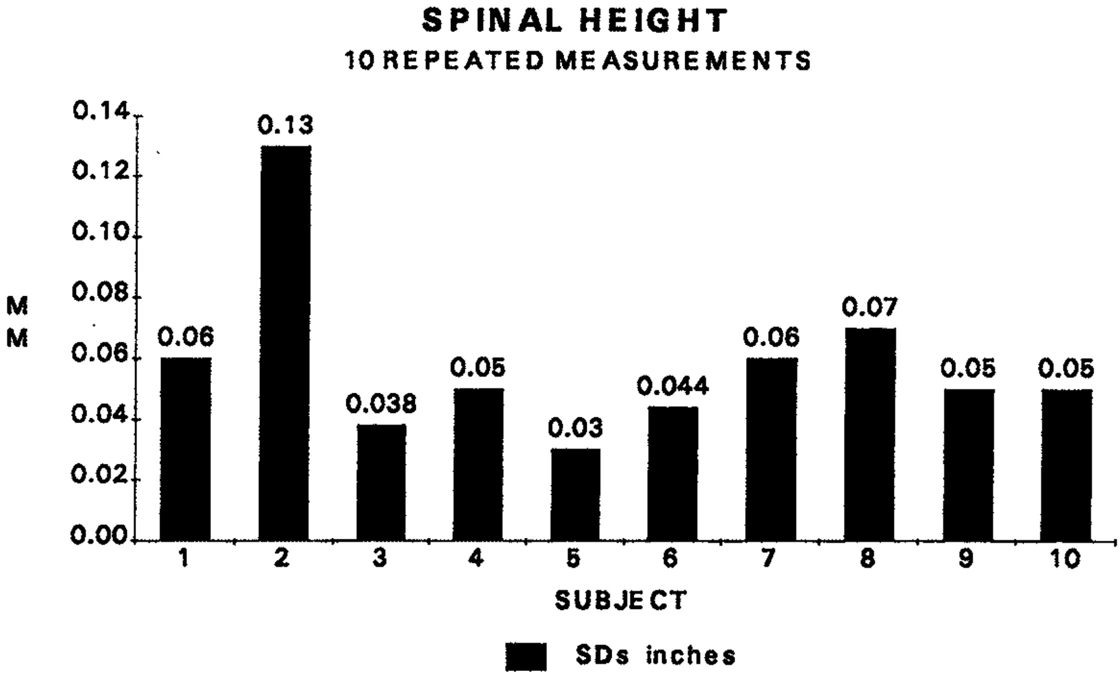
```
******Analysis of Variance--design 1******

Tests involving 'POSITION' Within-Subject Effect.
 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation          SS     DF      MS      F       Sig of F
 WITHIN+RESIDUAL            1.71    156     .01
 POSITION                    .72      2     .36    32.92      .000
 GROUP BY POSITION           .01      2     .00      .40      .673
 Observed Power at the .0500 Level
 Source of Variation    Noncentrality   Power-
 POSITION                  65.836       1.000
 GROUP BY POSITION           .794        .117

Tests involving 'TOM' Within-Subject Effect.
AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation           SS     DF      MS      F     Sig of F
 WITHIN+RESIDUAL              .80    156     .01
 TOM                          .00      2     .00     .08    .921
 GROUP BY TOM                 .00      2     .00     .29    .745
Source of Variation    Noncentrality   Power
 TOM                        .164        .064
 GROUP BY TOM               .589        .100

Tests involving 'POSITION BY TOM' Within-Subject Effect.
 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation              SS     DF       MS      F      Sig of F
 WITHIN+RESIDUAL                1.73    312      .01
 POSITION BY TOM                 .02      4      .00     .81     .522
 GROUP BY POSITION BY            .03      4      .01    1.45     .218
  TOM
 Observed Power at the .0500 Level
                               Noncen-
 Source of Variation           trality      Power
 POSITION BY TOM               3.226        .257
       GROUP BY POSITION BY         5.797        .448
```

(F values are greater than the alpha level showing nonsignificance between means of measurements.)

TABLE 7
PAIRED BONFERRONI
CONFIDENCE INTERVALS
NO LOWER BACK PAIN GROUP

	SUPINE 8 MINS	SUPINE 12MINS	WALK 4MINS	WALK 8MINS	WALK 12MINS
SUPINE 4 MINS	(-.05, .05)	(-.05,.05)	(-.05,.05)	(-.98,.92)	(-.05,.05)

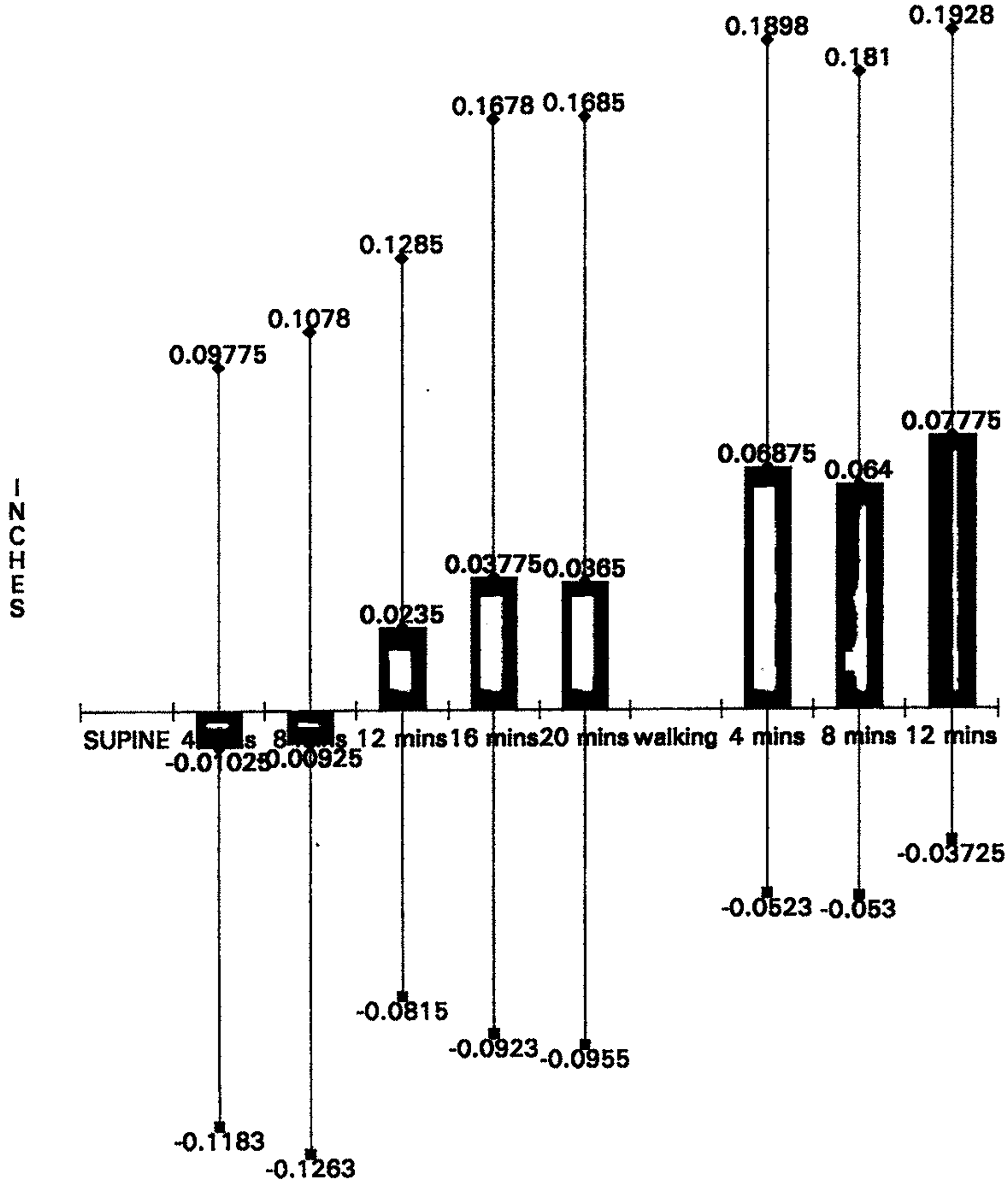
(Comparison of results of paired Bon ferrone testing for all intervals except supine 16mins. Since zero is included in all of the intervals, none are significantly different.)



Graph 1 shows the means of 10 repeated measurements for 10 subjects.

GRAPH 2

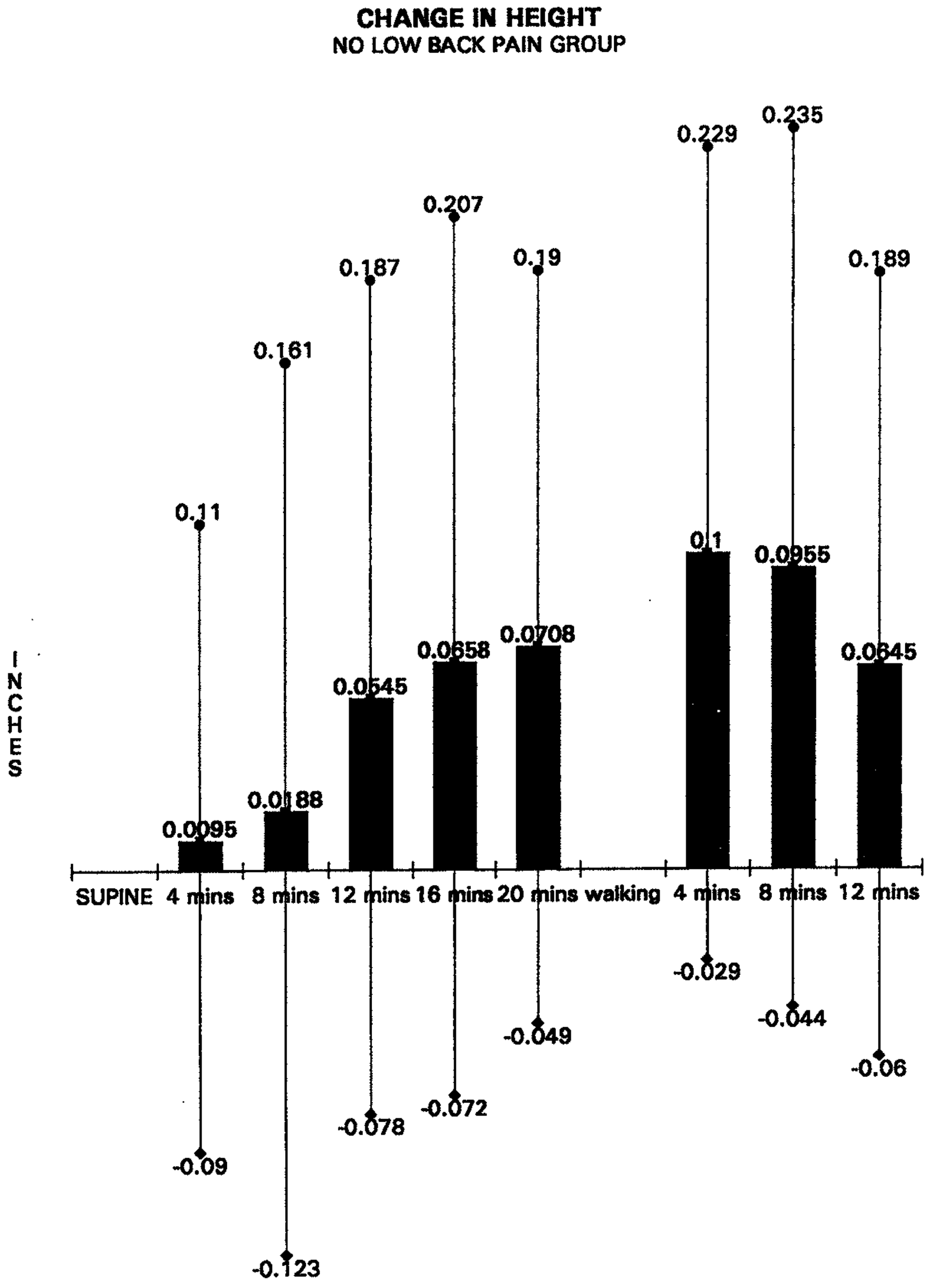
CHANGE IN HEIGHT
LOW BACK PAIN GROUP



INTERVAL MEANS + SDs

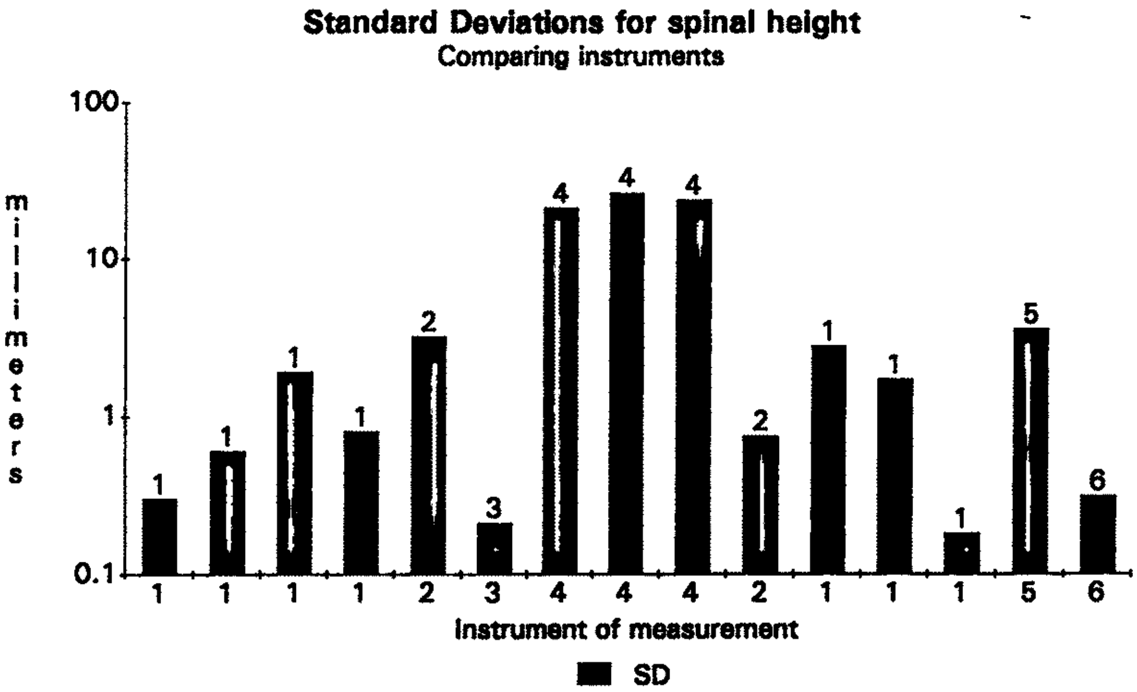
Repeated measurements show increases in mean spinal height supine and decreases walking

GRAPH 3



INTERVAL MEANS + SDs

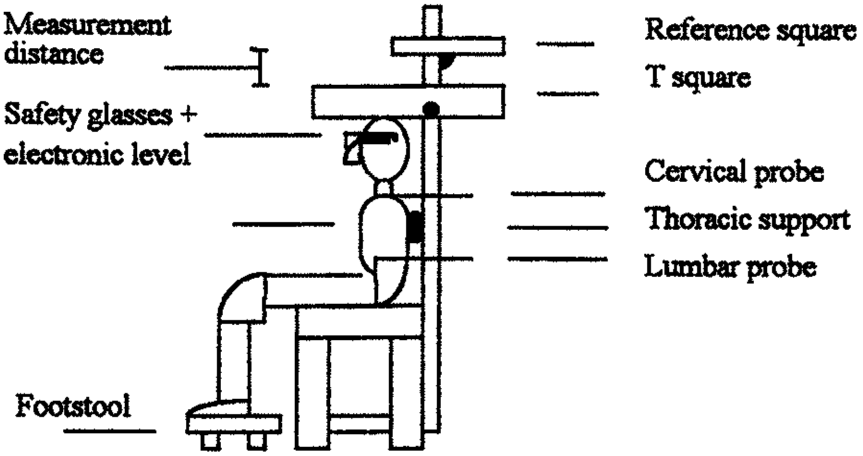
Repeated measurements show increases in mean spinal height supine and walking.



1. = stadiometer
2. = T square
3. = Tape measure
4. = Ultrasound
5. = Body calliper
6. = T chair

Graph 4 shows the mean standard deviations for instruments included in the literature review of this study. All of the studies were done under different conditions so these comparisons are relative.

FIGURE 1
"T CHAIR" CONSTRUCTED FOR THE MEASUREMENT OF SPINAL HEIGHT.



Dimensions:
height = 22"
width = 22"
depth = 18 "
Total height = 72"

(The footstool, T square, probes, thoracic support were all adjustable.)

APPENDIX B

Changes in Spinal Height with Unloading

Investigator: Dave Gregory PT

This is a study that will investigate variations in spinal height produced when lying down. The purpose is to see if there are measurable differences in height changes during and after lying down, between people with and without lower back pain. Subjects will participate on a voluntary basis and may drop out at any time during the measurement session. What you will be asked to do is mostly passive and requires walking, sitting and lying down. Your spinal height will be measure several times while sitting in a chair. In order to make the measurements as accurate as possible, glasses with an electronic level will be worn and bolts from a vertical metal frame will contact your back. Ten measurements will be made over a period of 30 minutes when walking and lying down. Because these are positions assumed every day there should be no discomfort or risk to those participating. If there are any questions concerning details of the study, the experimenter will answer them following the measurements. Thank you for your time.

I have read the above and am willing to participate in the study:

Subject ______________________ date________

Witness______________________ date________

Group____________ Number_________

APPENDIX C

DATA SHEET

Date ____________
Name ____________
Subject # ____________
Height ____________
Weight ____________
Sex ____________
Wrist diameter ____________
Time ____________
Reference ____________

Group ____________
Occupation ____________
Age ____________
Lower back pain? ____________
Frequency ____________
Duration ____________
Traumatic onset? ____________
History ____________
Bar width ____________

Baseline
1. ____________ 2. ____________ 3. ____________

Mean ____________ ____________mm

Fowler's position
4 minutes____________ ____________mm
8 minutes____________ ____________mm
12 minutes____________ ____________mm
16 minutes____________ ____________mm
20minutes____________ ____________mm

Walking
4 minutes____________ ____________mm
8 minutes____________ ____________mm
12 minutes____________ ____________mm

Mean____________mm SD____________mm