

RELIABILITY AND VALIDITY OF A NEW INSTRUMENT AND  
PROCEDURES FOR MEASURING SCOLIOSIS

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## ABSTRACT

**Background and Purpose:** Scoliosis is a deformity of the spine in which there are one or more lateral curvatures deviating from the midline in the coronal plane. A non-invasive method of measuring scoliosis would allow health care professionals to monitor the progression of scoliosis without the risks involved with radiographic exposure. The purpose of this study was to examine the test-retest reliability and validity of the Pneu-Measure and Analyze Posture (M.A.P.), a new instrument for measuring, scoliosis,

**Methods:** Nineteen subjects, age 9-18 years, participated with informed assent. Experimenters used palpation to locate and map spinal curvatures using Pneu-M.A.P. procedures during, test and retest sessions, separated by a 30-minute rest period. Intraclass correlation coefficients (ICC) and Pearson r correlation coefficients were used to analyze test-retest reliability and the relationship with Cobb's angle respectively.

**Results:** Upper Curve intra-rater reliability was good ( $r = 0.81$ ). The correlation with Cobb's angle for the Upper Curve was significant,  $r = .60$  ( $p = .01$ ). Intra-class correlation coefficient and correlation with Cobb's angle for the Lower Curve was poor,  $r = .17$  and  $r = -0.11$ , respectively.

**Conclusion and Discussion:** The Pneu--M.A.P has potential to be a clinically useful instrument for measuring primary Scoliotic curves, but additional research is required to examine inter-rater reliability, stabilization procedures, and sensitivity to curves of varying, severity

## INTRODUCTION

Scoliosis is a deformity of the spine in which there are one or more lateral curvatures deviating, from the midline in the coronal plane (Magee, 1997). These lateral deviations may be present in the cervical, thoracic, or lumbar regions of the vertebral column. A lateral curvature of greater than 10 degrees is usually considered to be clinically significant. Scoliosis can be divided into structural and nonstructural types. Structural scoliosis is defined as a curvature that does not correct with forward trunk-flexion (Cassella & Hall, 1991). Structural scoliosis also has a rotational component in which the anterior aspect of the vertebral bodies within the curvature rotate toward the convex side and the spinous processes rotate toward the concave side of the curve. Nonstructural Scoliotic curves correct when the spine is flexed forward and have no rotary component (Cassella, 1991).

Lonstein's (1982) review of the literature reported a prevalence rate of 0.4% to .4%. This variability reflects the wide range of inclusion criteria used by different authors; some authors reported all curves over 5 degrees and others reported only curves greater than 20 degrees. These findings were supported in a literature review by Pearsall (1992), who stated that .13% to 13% of the population have some degree of scoliosis. Approximately 10% of detected structural curves grow progressively more severe over time (Farady, 1983). Structural curves increase at rates of up to 10 degrees per year (Dickson, 1980).

There are a number of potential deleterious health effects associated with untreated structural scoliosis. Severe scoliosis causes a deformed and rigid thoracic cage and may contribute to impaired respiratory function, including a reduction in function including a reduction in lung volume, vital capacity, and maximal voluntary ventilation (Rothman and Simeone, 1982)

Adults with untreated severe scoliosis have an increased incidence of back pain; diminished work capacity, cardiopulmonary disease, and mortality rate twice that of the normal adult population (Farady, 1983). In addition, adults with scoliosis have been found to experience self-consciousness and tend to avoid activities requiring, social contact. (Farady, 1983))

Early identification and intervention has been shown to prevent the need for surgery by halting or slowing, the progression of the structural Scoliotic curve (Montgomery & Willner, 1993; Bunnell, 1984). The primary goal of intervention is to prevent curve progression and its associated sequelae, including cosmetic deformity, pain and cardiopulmonary impairments (Cailliet, 1975). Interventions can be divided into three categories: monitoring progression, bracing, and surgery (Rothman & Simeone, 1982). The intervention chosen often depends on the age of the patient, the severity of the curvature, and the likelihood of curve progression (Rothman & Simeone, 1982). In children who have not reached skeletal maturity, mild to moderate curves (<20 degrees) are generally monitored for changes in the degree of curvature. Moderate curves ranging from 20 and 40 degrees can be treated with

bracing (Pearsall, 1992) and severe curves of greater than 45 degrees usually require surgical intervention (Montgomery & Willner, 1993).

The Cobb method is currently the standard by which scoliosis is evaluated. The Cobb method is a radiographic technique standardized by the Scoliosis Research Society (Cailliet, 1975). This radiographic technique consists of identifying the end vertebrae of the curve (Fig. 1). The end vertebrae are defined as the inferior- and superior-most segments that are inclined toward the concavity of the curvature being measured. A line is then drawn along the superior surface of the vertebra body of each of these two vertebrae. A perpendicular line is dropped from each of these lines. The angle formed by the two perpendicular lines is considered to be Cobb's angle, and represents the measurement of the curve (Rothman & Simeone, 1982). The Cobb method is clinically accepted as accurate and is currently in widespread use.

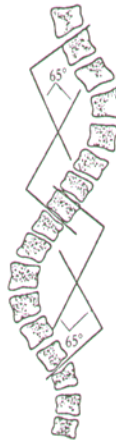


Figure 1. Technique used to measure Cobb's Angle.

An accurate non-invasive method for periodically measuring and documenting changes in the severity of the Scoliotic curve can aid the practitioner and family in determining the appropriate intervention. The greater the sensitivity of detecting and measuring, changes in the curve the earlier non-invasive interventions can be applied, thereby reducing the likelihood of a need for surgical intervention. Various methods of measuring scoliosis have been documented in the literature. Willner and Willner (1982) described the use of *moiré contour topography* in evaluating minor Scoliotic curves. This method consists of projecting light through a special grid onto the subject's back. The light source creates a series of contour lines on the subject's back, much like the contour lines of a topographical map. Asymmetries in the contour lines indicate spinal deformity. Moiré topography has the advantage of being a non-invasive technique and a quick screening tool. While some researchers have shown a correlation between the surface contour deviations and Cobb's angle (Willner &

Willner, 1982), others have questioned this correlation (Sójbberg & Hórlyck, 1982). In addition, this method may create many false positives (Frobin & Hierholzer, 1982).

*Stereo-radiography* is another surface technique used to assess the degree of Scoliotic curvature. This method encompasses a variety of techniques, all of which involve using paired radiographic images taken from two different angles behind the subject (Saraste & Ostman, 1986). Modifications of this technique have been made in order to automate the radiographic imaging, equipment, thereby reducing the delay between radiographs. A method of stereo radiography has been developed which does not require the use of invasive radio-opaque skeletal markers. However, stereo radiography has the disadvantage of requiring exposure to radiation. Also, an inherent lack of X-ray clarity may create difficulty in interpretation of the results (Saraste & Ostman, 1986).

Stokes et al. (1987) described a technique known as *line raster stereography*, developed by Frobin & Hierholzer (1978). Using line raster stereography, Stokes et al. found a significant correlation with Cobb's angle, both for an upper curve ( $r = .73$ ,  $n = 56$ ) and a lower curve ( $r = .82$ ,  $n = 56$ ). Line raster stereography measures the rotation of the surface of the back by projecting a square grid pattern of light onto the patient's back. The results are photographed from a prescribed angle behind the patient and surface curvatures are calculated from the data gathered.

Another tool used clinically to assess scoliosis is the *Scoliometer*. The Scoliometer is a small rectangular measurement instrument, which is placed over the spinous processes at the level of maximal paraspinal prominence (Skaggs & Bassett, 1996). The Scoliometer can be used to quantify the degree of rib prominence and has been described as a reproducible means of quantifying the angle of trunk-rotation, which has been correlated to Cobb's angle ( $r = .89$ ,  $n = 1065$ ) (Bunnell, 1984). However, like the moiré surface topography method, the Scoliometer has been criticized for producing an excessive number of false positives when used in screening (Pearsall et al., 1992). Pearsall, et al., also described the use of the back-contour device for measurement of axial trunk rotation. As with the Scoliometer, the subject is assessed with the back contour device while in a forward-bending posture. The back contour device consists of a level frame, which is penetrated by a series of closely spaced moveable rods. The rods are placed on the patient's spine and then locked in place, thereby producing a negative image of the surface contour of the spine.

A final technique used to assess abnormalities of back surface contours associated with scoliosis is the integrated shape investigation system. Weisz et al. (1988) found a good correlation between lateral asymmetries as assessed by the integrated shape investigation system and Cobb's angle measurements ( $r = .77$ ,  $n = 56$ ). The integrated shape investigation system is a computer imaging technique in which a light is projected from the computer onto the patient's back. A special scanner is used to detect and process the lines formed on the surface of the back by the light. A computer then formulates a three-dimensional image of patient's back surface using these data. Advantages to the shape investigation system

method include its reproducibility, accuracy, lack of exposure to radiation, speed of administration, and good correlation with Cobb's angle. However, the integrated shape investigation system technique requires the use of several large and costly pieces of equipment, including a special scanner, computer console, and a plotter (Weisz et al., 1988). Although numerous measurement methods have been described in the literature, it is our understanding that none is in widespread clinical use, perhaps because they require repeated exposure to X-rays or costly equipment, or because they may not have been shown to reliably measure Scoliotic curves. It therefore seems plausible to investigate other methods that can be shown to be reliable, valid, easy-to-use, and cost effective.

The most frequently used assessment technique is Cobb's angle. However, with this technique, the patient must be subjected to repeated radiographic exposures. This is problematic because the progressive nature of scoliosis makes it necessary to obtain radiographs every three to six months, depending on the nature of the curve (Cassella & Hall, 1991). Current radiographic techniques have significantly decreased the level of exposure to radiation for individual X-rays (NIH, 1999) but harmful effects may result from repeated exposure. Alman and Mattson (1996) found a high absorption rate of radiation by certain organs, including, the breasts, thyroid gland, lungs, esophagus, and gonads with lumbar and thoracic spine radiographs. The authors concluded that the cumulative dosage of radiation caused by repeated X-rays could reach dangerous levels. A non-invasive measurement technique would allow for more frequent monitoring of the curve without associated exposure to radiation and undue expense. The Pneu-Measure and Analyze Posture (Pneu-M.A.P.) is a recently developed instrument that the manufacturer suggests can be used to measure scoliosis (Pneumex, Inc., 1999).

However, our search of the literature found no evidence to support its reliability or validity. The reliability and validity must be established-before the clinical usefulness of the Pneu-M.A.P. can be considered. The purpose of this study, therefore, was to examine the test-retest reliability of the Pneu-M.A.P. when used to measure scoliosis, and to assess its validity by comparing the measurements generated by the Pneu-M.A.P. to Cobb's angle.

## **METHODS**

### **Subjects**

Twenty-one subjects initially participated in this study with informed consent. Subjects were recruited as volunteers selected from the patient population of a local pediatric orthopedic surgeon in Missoula, MT. Subjects were limited to those with a diagnosis of functional or structural scoliosis. For the purpose of comparing Pneu-M.A.P measurements to Cobb's angle, subjects with radiographs taken within six

months prior to our data collection were used. Two subjects were excluded from the study secondary to equipment failure during, the measurement procedure. Three additional subjects were excluded from the validity portion of the study because their most recent radiographs were greater than six months old. Therefore, the results from 19 subjects were used to assess intra-rater reliability, and the results for 16 subjects were correlated with Cobb's angle to investigate the validity of the Pneu-M.A.P. The age, height, and mass of each subject were collected (See Table 1).

	Age (years)	Height (cm)	Mass (kg)	Body Mass Index (kg/m <sup>2</sup> )
Mean	14.2	160.9	52.3	20.0
Range	9 - 18	137.8 - 175.3	31.8 – 65.5	16.8 – 24.0
Std. Deviation	2.2	9.9	9.3	1.9

Table 1: Descriptive Statistics for Subject Sample (n=19)

This study was conducted in the Clinical Kinesiology Laboratory in the Skaggs Building, on the University of Montana campus. Written, informed consent was obtained from each subject or from a parent or guardian if the subject was under the age of 18 years. If the subject was under the age of 18, a written form of assent was also obtained. This study was approved by the Institutional Review Board for the Use of Human Subjects in Research of the University of Montana.

### Instrumentation

The measurements were made using the Pneu-M.A.P., an instrument manufactured by Pneumex, Inc. (804 Airport Way, Sandpoint, IID, U.S.A). The information from the M.A.P. was entered into the Pneumex Measure and Analyze Scoliosis software program\_(Pneumex Inc.) that generated a graphic presentation of the curve and calculated the inverse slope, or "percent shift" (the terminology used by the software program) of the curves.

### Testing Procedures

**Subject preparation:** Subjects were informed that they would be wearing hospital gowns to allow exposure of their backs. They were familiarized with the mapping, instrument, the palpation and measurement procedures, and the use of a washable marker to identify landmarks on their spines. The subjects were informed that we would take two measurements separated by a '10-minute rest and relaxation period. Finally, subjects were informed of their ability to access the research results at the completion of the study.

**Preparatory Measurement Procedure:** The M.A.P. was leveled prior to screening, using the intrinsic leveling device. The pen for the grid was placed in the stylus. The gowned subject was positioned in front of map with his or her heels placed against

the base of the instrument. Once the subject was properly aligned, we assured that the height of the frame was adjusted so that the stylus reached the sacrum when it was at the bottom of the grid (see Figure.2). Before conducting the actual data collection, the subject was instructed as follows: "Take a deep breath. Place your hands at your side. Relax and stand normally. Focus on the picture directly in front of you on the wall." The subject was also instructed to keep their weight evenly distributed over both feet.

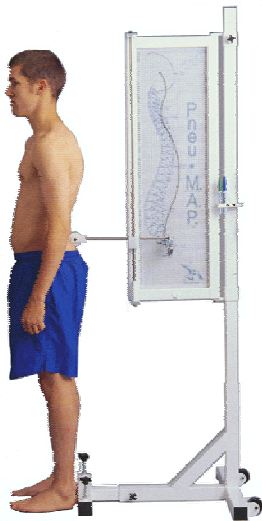


Figure 2. Alignment of Pneu-M.A.P and subject.

The center of the 5th lumbar (L5) spinous process was marked. This point was determined by its relationship to the iliac crests. A second mark was placed over the center of the C7 spinous process. This point was determined by asking the subject to rotate his or her head; C7 demonstrated significantly more movement than T I. We centered the stylus on the lumbosacral junction (L5-S I). The pen was raised to the cervico-thoracic junction (C7-T I). The point at which the pen fell either directly over or in the same transverse plane as the C7 spinous process (if the two points were not in vertical alignment) was marked with the stylus pen. If the pen did not fall directly over the previously marked C7 spinous process during this process, the subject was judged to have a "lateral shift". An assistant placed a hand on the subject's shoulder and hip to align C7 directly over L5 and to prevent him or her from swaying.

**Mapping and Measurement:** The stylus pen was used to draw a reference line connecting C7 and L5. The subject was then carefully aligned in front of a plumb line. The plumb line was used to ensure that the reference line drawn on the subject's spine remained vertical. Once again, the assistant placed a hand on the subject's shoulder and hip to maintain alignment of C7 directly over L5 and to prevent him or her from swaying during the palpation process.



The mapping procedure followed a superior-to-inferior progression down the spine. The examiner palpated and marked each spinous process using a washable felt-tipped pen. Once all of the spinous processes were marked, the vertebral level at which the spine first deviated from the C7-L5 longitudinal axis was marked. This point was designated as point A (see Figure 3), and labeled as such on the subject's skin. Next the examiner located the apex of the curve (the marked spinous process farthest from the reference line). This point was designated point B and labeled on the subject's skin. These steps were repeated at the point of convergence (point C), where the spine intersected the reference line below the apex. A lower curve was identified if the spine deviated from the vertical reference line a second time. If a lower curve was present, we continued the mapping procedure, adding a point D and E (apex and intersection, respectively, Figure 3). The examiner noted the vertebral level corresponding to points A, B, C, D, and E. We measured and recorded the distance from the reference line to the following points: 1) the lateral shift, 2) point B, and 3) point D. The side of convexity of the thoracic curve and lateral shift were noted.

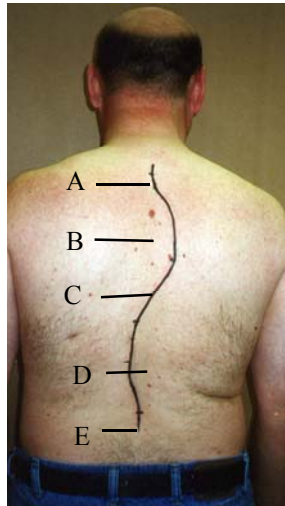


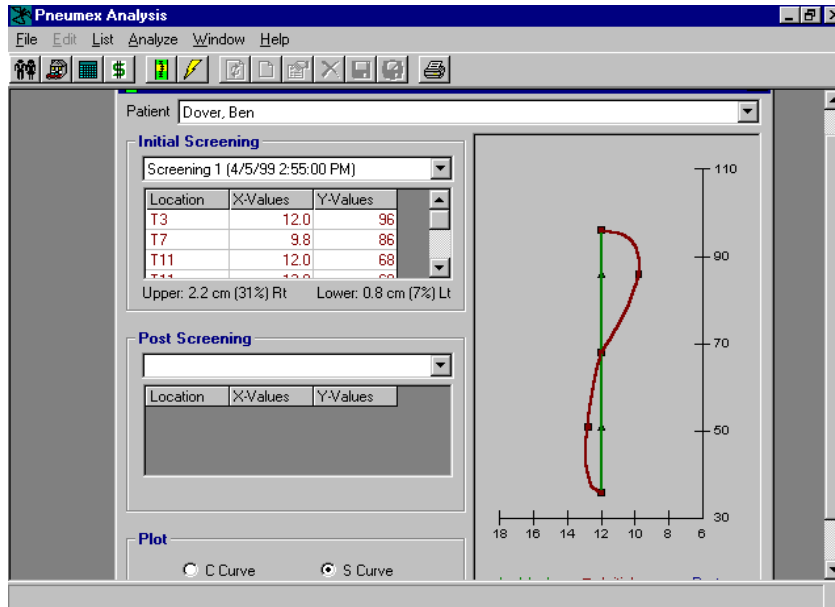
Figure 3. Reference points (A, B, C, D, and E) used in the measurement process.

The subject was then re-aligned in front of the Pneu-M.A.P. A horizontal line corresponding with each of the labeled vertebral levels (A, B, C, D, and E) was marked on the grid. Care was taken to make these clean, straight and singular lines. An assistant recorded the numerical grid levels corresponding, to each point.

Following the measurement procedure, the examiner carefully washed the subject's back with soap and warm water. Care was taken to ensure the removal of all pen markings. The subject was then escorted to a separate room, where they were asked to sit quietly for 30 minutes so that any residual skin changes resulting from the measurement process and subsequent washing would be allowed to subside. Following this rest period, the subjects were re-measured by the same examiner using the same testing procedure.

## Data Reduction

Pneumex Measure and Analyze Scoliosis software program (Pneumex, Inc., Sandpoint, ID, USA) was used to reduce the data gathered on the Pneu-M.A.P. grid into a form that could be statistically analyzed. For each subject, the grid level corresponding to each of the five vertebral landmarks described above was entered into the computer.



(Figure 4) Sample of computer mapping of S curve

The measured distance (in centimeters) from the apex back to the C7-S I longitudinal midline (reference line) and the orientation of the convexity of the curve (right or left) were also entered into the computer. With these data, the computer calculated the percent inverse slope of the curve (horizontal displacement [run] ÷ vertical displacement (rise). After measurements had been performed on all subjects, the Cobb's angles for the appropriate curve were obtained from the subject's medical records. These values were recorded.

Operational definitions for the data reduction were as follows:

Test Upper Curve Re-Test Upper Curve	An upper curve was defined as either the apex of a C-curve located in the lumbar spine or of the lower curve if an S- curve was present
Test Lower Curve Re-test Lower Curve	A lower curve was defined as either the apex of a C-curve located in the lumbar spine or of the lower curve if an S-curve was present
Upper Cobb's	The Cobb's angle measurement defined in physician's records as a thoracic curve.
Lower Cobb's	The Cobb's angle measurement defined in physician's records lumbar curve

Table 2. Operational definitions for data reduction-.'

If a curve was identified by Cobb's angle but not in either the test or retest, it was recorded as zero for the test or retest. If the curve was identified in the test and/or re-test, but not by Cobb's angle, it was recorded as zero for Cobb's angle. A curve was recorded .as non-existent if it was not detected by test, re-test and Cobb's angle measurements.

### Data Analysis

Descriptive statistics for the mean, range, and standard deviation were tabulated for the percent inverse slope of the curves. A one-way analysis of variance (ANOVA) was used to examine if the test and retest measurements differed. An intra-class correlation coefficient (ICC) (2, 1) was used to examine the reliability between the test and re-test measurements. In addition, a standard error of measurement (SEM) was calculated to examine the precision of the measurements.

The validity of the method was examined using a Pearson product-moment correlation coefficient (Pearson r) to identify the relationship between the appropriate slope as determined by the M.A.P. methodology and the Cobb's angle. We elected to correlate Cobb's angle measurements to the test measurement values because we believed that this test measurement was more representative of clinic conditions.

The percentages of false positives and false negatives were also calculated. A false positive was defined as a curve measured in the test measurement that did not have a corresponding Cobb's angle. The calculation procedure for the percent of false positives was as follows: (the number of false positives divided by 16) x 100. A false negative was defined as a curve that was not identified in the test measurement but was identified by the physician on the radiograph. The calculation procedure for the percent of false negatives was as follows: (the number of false negatives divided by 16) x 100.

The ranges for the ICC's were set as follows: 0.90-0.99 = high; 0.80-0.89 = good; 0.70-0.79 = fair;  $\leq 0.69$  = poor (Currier, 1990). The apriori level of significance was set at  $p \leq 0.05$  for the Pearson correlation coefficient. All data were analyzed with the SYSTAT software statistical package (SPSS Inc., 444 No. Michigan Ave., Chicago, IL, 60611).

## RESULTS

Four subjects experienced dizziness during the measurement procedure which required a brief rest period and subsequent re-alignment. In three cases, subjects were observed to have a C-curve during the test measurement and an S-curve during the retest measurement, or vice versa.

The descriptive statistics of test-retest measurements and the results of the one-way ANOVA are outlined in Table 3. The test and retest measurements did not differ.

Test	Mean (% Inverse slope)	Range (% Inverse slope)	Std. Dev. (% Inverse slope)	F	P
Upper curve Test	10.6	0.0 – 33.0	7.9	0.0	1.0
Upper curve Re-Test	10.6	0.0 – 28.0	6.6		
Lower Curve Test	7.1	0.0 – 14.0	4.4	2.1	.17
Lower Curve Re-Test	9.9	0.0 – 17.0	6.5		

Table 3. Descriptive Statistics and Results of One-Way ANOVA for measurements of Upper and Lower curves (n=19)

The ICC for the Upper Curve Test-Retest measurements was 0.81. The SEM for the upper curve measurements was 3.46. The ICC for the Lower Curve Test-Retest

measurements was 0.17 and the SEM for the lower curve measurements was 11.34. The mean Cobb's angle of the Upper Curve was  $14.3^\circ = 10.9$ .

The Pearson  $r$  value for Upper Cobb's Angle and Test Upper Curve was .60 ( $p=0.001$ ). The Pearson  $r$  value for Lower Cobb's Angle and Test Lower Curve was -0.11 ( $p=.75$ ). The false positive rate was 13% and the false negative rate was 6% for measurements of the upper curve.

## DISCUSSION

An ideal tool for measuring scoliosis would be reliable, valid (results comparable to Cobb's angle), noninvasive, quantifiable, and easy to use. Our study was able to shed light on the ability of the Pneu-M.A.P. to fulfill these requirements.

**Reliability:** The results of our study indicated that the Pneu-M.A.P. has good intrarater reliability when used to measure the thoracic (primary) curve. However, its reliability was poor when used to assess the lumbar (secondary) curve. There are many potential explanations for the variability found in our test-retest measurements. One primary contributing factor was the method of stabilization used for the subject. The subject was stabilized manually at the subject's hip and shoulders. Although this method helps to minimize lateral sway, it did not prevent perturbations in the transverse plane (i.e. rotation). Trunk rotation or pelvic rotation, or both, may have affected the placement of the reference line as well as bring about movement of the skin relative to the underlying bony landmarks. It seems possible that the rotation may have affected the actual curvature of the spine. This may have contributed to the variability in the curve characteristics between tests and retests. The alignment and stabilization may also have been contributing factors in the three cases in which the subject had a C-curve on the test and an S-curve on the retest, or vice versa.

During the measurement, subjects were required to stand still for up to a maximum of 10 minutes. Four subjects experienced dizziness, thereby requiring a temporary suspension of measurement activities. This rest period was followed by a realignment process which may have added a potential source of error to the measurement, because there was no way to ensure that they were realigned exactly as they had been prior to stopping the measurement process.

Finally, the Pneu-M.A.P. measurement technique required substantial palpation skills. The examiner in this study was a Physical Therapy graduate student in her final year of studies. She was not a seasoned clinician, and this could have introduced a potential source of error. Results may have been different if measurements were performed by an expert clinician.

**Validity:** Our results showed that only 36% ( $r = .60$ ,  $r^2 = .36$ ) of the variance among Cobb's angle measurements could be explained by variance in Pneu-M.A.P. measurements. Many measurements techniques have been compared to Cobb's angle. Although Willner & Willner (1982) reported a statistically significant correlation between number of moiré contour lines (fringes) and Cobb's angle measurements, these results were not substantiated by Sojbjerg, and Horlyck (1982). Bunnell (1984) found a significant correlation between measurements taken by the Scoliometer and Cobb's angle measurements ( $r = 0.89$ ). The integrated shape investigation system was also found to have a correlation with Cobb's angle ( $r = .77$ ). Although the results of our study revealed a significant correlation between the percent inverse slope as measured by the Pneu-M.A.P. and Cobb's angle measurements ( $r = 0.60$ ), this correlation was not as strong as those found for other techniques

An excessive number of false positives generated by a measurement tool can lead to increased referrals to physicians and overuse of the health care system. One of the challenges of many measurement instruments is to increase accuracy and to avoid false positives and false negatives. Willner (1982) reported that the moiré measurement device has a 29% rate of false positives, and Willner and Willner (1982) reported a 0% false negative rate. Bunnell (1984) found that the Scoliometer had a false positive rate of 52% ( $n=1065$ ). The results of our study using the Pneu-M.A.P. revealed a false positive rate of 13% and a false negative rate of 6% for measurements of the upper curve. In this regard, the Pneu-M.A.P. is comparable to other devices.

In addition to the factors contributing to the reliability error mentioned above, a number of factors relate only to the validity portion of this study. The Cobb's angle measurements obtained from the physician may also have contributed to the variability between the test measurement and Cobb's angle. The postural alignment used to take the X-rays for Cobb's angle is unknown. Additionally, we do not know whether Cobb's angle measurements were taken for all apparent curves or whether they were taken only for those curves of clinical significance. A non-existent curve was recorded as a zero and this influenced the statistical analysis of the relationship between the numbers generated. It is also unknown whether the subjects were instructed to remove their shoes prior to being X-rayed. The presence of heel lifts or other orthotics may have affected the alignment of the spine.

Future research using the Pneu-M.A.P. could address ways to better control subject stabilization for maintaining vertical and rotational alignment throughout the measurement process, a larger sample size may allow for a more selective examination of the relationship of the severity of the curve to the reliability of the Pneu-M.A.P.

Furthermore, additional research could address inter-rater reliability of the device. It would also be interesting to investigate the Pneu-M.A.P.'s ability to detect changes in the Scoliotic curve over time

## CONCLUSION

This study examined the intra-rater test-retest reliability and the validity of the Pneu-M.A.P. instrument and procedures for measuring scoliosis. Our results indicated that intra-rater reliability was good ( $r = .81$ ) despite using a small sample size ( $n = 16$ ) with relatively mild curves (mean Cobb's angle =  $14.3^\circ \pm 10.9$ ). Additional research with a larger sample size and greater range of curve severities is indicated. This research could explore whether the reliability and validity of the Pneu-M.A.P. measurements vary with the severity of the curve. Once the ranges for which the Pneu-M.A.P. is most sensitive can be identified, then its clinical use can be more clearly defined. The Pneu-M.A.P. has potential to be a clinically useful instrument for measuring Scoliotic curves. Additional research must be conducted to refine and standardize the methods of stabilization and to examine inter-tester reliability before it should be introduced as an alternative method for measuring scoliosis.

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