Biology of Sport, Vol. 20 N°1, 2003

A NEW INSTRUMENT FOR RECORDING THE SPINE CONTOUROGRAPH

V.Hein
Faculty of Exercise and Sports Sciences, University of Tartu, Tartu, Estonia

Abstract. The purpose of this investigation was to evaluate the acceptability of a new instrument for recording the contourograph of spine curvature. The instrument based on distance measurements from the points of the spine curvature to the vertical line by the infrared optical sensor. The acceptability of measurements was assessed. The agreement of the test-retest measurements recorded using the designed instrument was analysed by the limits of agreement techniques. The validation of the lumbarsacrum angle calculated on the spine contourograph was evaluated against the measurements of the inclinometer. The amount of disagreement between test-retest values of the measured points on the spine contourograph calculated using the limits of agreement technique statistics ranged from 4.9% to 6.2%. The results of this study allowed to suggest that the designed instrument was a sensitive tool in assessing a different impact on the spine curvature. ***(Biol.Sport 20:79-89, 2003)***

Key words: Spine contourograph - Vertebral angle - Measurement method

Introduction

The curves of the spinal curvature are often used to characterise the posture [1,5]. Various methods of measuring the spinal curves have been investigated [6,7,10,11,13,19]. The use of different types of inclinometers and flexicurves for measuring the angles of the spine curvature is well spread as the test-retest reliability of these has been found to be clinically acceptable. In addition, more modern and complicated systems such as ultrasonography, and video raster-stereography have been developed for the measurement and assessment of the shape of the human back [15,16]. Hackenberg, *et.al.* [12] and Drerup, *et al.* [8] have found raster- stereography to be a suitable tool for analyzing the three - dimensional correction of spinal deformities. Also, the performance of the new

---

Reprint request to: Dr Vello Hein, University of Tartu, 18 Ülikooli Str., EE 50090 Tartu, Estonia; Tel.: 372-7-375382, Fax: 372-7-375373 or 375440, e-mail: vello@ut.ee

ultrasonography -based instrument for spatial kinematic analysis of the spine was validated against a digital inclinometer [9].

However, Lamb [11] has recently noted, that the test- retest reliability expressed even by the high intraclass correlation (say >0.80) between repeated measurements does not equate to the good agreement. Boone, *et al.* [4] have found the reliability of the goniometer measurements to be with an intratester variation of 4°. They have noted that joint motion should differ by at least 5° before a true increase or decrease in the joint motion may be recorded. Several investigators [7,19] have found the difference between the test- retest measurements of the spine curvature to be of 4-7°. It means, that to estimate an impact of the physical exercises of the correction treatment procedure on the spine curvature angles (which mean values range from 30° -to 40°), the initial values must differ from the final more than 16%. It is complicated to gain such amount of change during the treatment procedure. Therefore, there is a need for a simple, accurate and no expensive non-contact method for measuring the sagittal profile of the spine to determine the aberration of the posture or to evaluate the effectiveness of treatment procedures.

This report presents a new instrument for measuring the instantaneous shape of the vertebral column that can supplement the above noted measurements.

Material and Methods

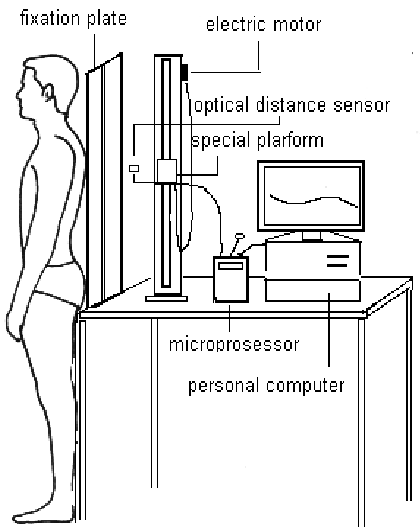

Fig. 1
Instrument for recording the spine curvature contourograph

Instrumentation: A new instrument was constructed to measure the spinal curvature (Fig. 1). The compact, high sensitive infrared optical distance sensor SHARP GP 2D02 was used for recording the distance between the fixed vertical line and the points of the spine curvature. The sensor was fixed to the special platform, which moved on the wheels fitted into the rails of the metal vertical rod. The up and down movement of the platform with the sensor took place due to the power of the electric motor. In addition, the design of the instrument enables to stop the platform movement at each point for recording the distance between the selected point of the spine curvature and the vertical plane. The distances from vertically moving sensor to the spine curvature were recorded during the down-movement. The distance of the sensor from the spine curvature points between 60 mm to 300 mm ensured the precise distance recording in mm. The interval between the points on the vertical rod was 5 mm. The recording time of one contourograph was 13 s. The exact location of the infrared ray of the distance sensor along the spine curvature was controlled by the red light of the diotlaser. The length of the wave was 670 nm and the power lower than 1 mV. In order to avoid the body from swaying during the measurement procedure the subject was asked to contact with the fixed support plate. The slit of an inch in width was constructed into the centre of the plate enabling the spread of infrared wave between the sensor and the back. The data acquisition was controlled by the custom software of the microprocessor. The software was written in the Basic programming language. The recorded data were downloaded into a personal computer PC for the further processing, analysis and display. Command communication between the portable unit and the PC was handled through the PC serial port at a baud rate of 9. 600 bit/s. Additional PC software was written in order to convert the data for processing with MS Excel. The memory of the microprocessor enabled to record and save 50 spine curvature measurements.

Experimental design: The subject stood in upright position. The interspaces of L5/S1 and T1/T2 were marked by the special mark pencil. The measurement was taken in normal standing position. The constant distance from the instrument to the subject was used during all measurements. Before the measurement procedure the exact location of the infrared ray of the distance sensor on the upper marked point (T1/T2) was established by the red light of the diotlaser. The down movement of the platform with sensor was stopped at the point of L5/S1 (Fig. 2). This procedure allowed to obtain the spine contourograph between the interpaces of T1/T2 and L5/S1 for further calculation of the angles of the spine curvature. During the next measurement procedure the movement of the sensor was not stopped at the point of L5/S1. After that the subject was asked to remove from the measurement place and

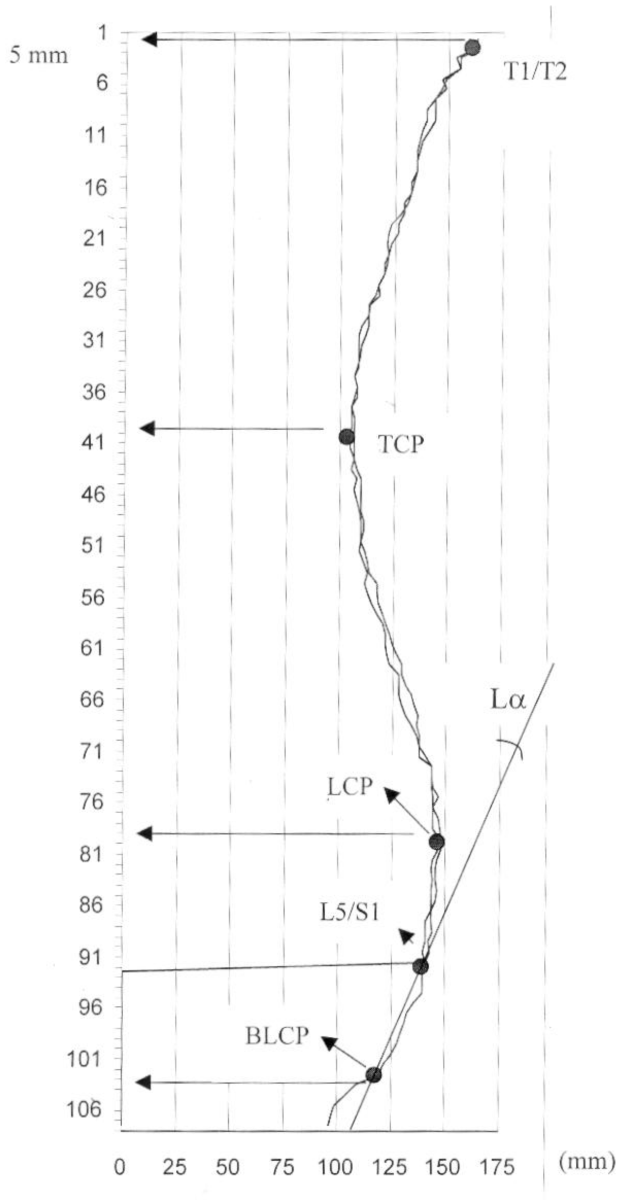

Fig. 2
The characteristics of the contourograph of spine curvature

the inclinometer was placed along the line of the vertebrae at the point of L5/S1 according to the method described by Toppenberg and Bullock [18]. The vertically hanging needle thus provided a reference for the inclination of the back at this position. Then the measurement according to the second procedure was repeated.

Reliability of measurement: To test the reliability between the two measurements four points on the spinal contourograph were selected: the interspaces of T1/T2, L5/S1 and maximum curvature points in the thoracic (TCP) and lumbar (LCP) region of spine (Fig. 2). The mean differences between repeated measurements and the standard deviation (SD) of these differences multiplied by 1.96 allowed calculating the limits of agreement.

The validation of the lumbarsacrum angle calculated on the spine contourograph obtained by the designed instrument was evaluated against the measurements of the inclinometer.

Calculation of the lumbarsacrum angle: On the lumbar lordosis curves the 14th point (BLCP) below the point L5/S1 was chosen. The distance between these points corresponded to the length of the support surface of the inclinometer during the measurement of the sacrum inclination. The curve between BLCP and L5/S1 was approximated with straight lines with the aid of the software package MS Excel. The angle of the lumbarsacrum ($L\alpha$) was determined by the approximated straight line between the points BLCP and L5/S1 and the vertical line.

Subjects: Ten male students of the department of the physical education participated in this investigation. Their mean age, height and weight were 19.0±1.5yrs., 181±5 cm and 76±9 kg, respectively. Informed consent was obtained from each subject beforehand.

Statistical analysis: SPSS programs were used to analyse the data. The Limits of Agreement technique (LoA) was used to estimate the test - retest reliability [3]. According to this technique the normal distribution of the test - retest differences was controlled by the Shapiro-Wilks test, the difference between the test - retest means was estimated by the paired t - test and the relation between the test - retest differences (expressed without sign) and the test - retest means were calculated by Pearson product moment correlation. The $P<0.05$ level was selected as the criteria of statistical significance.

Results

Table 1 presents the test - retest measurements of the distances between the spine curvature points and the vertical. Table 2 presents the limits of the agreement statistics for the test - retest data. The Shapiro-Wilks test revealed the test-retest

Table 1
Measurements of the distances (mm) from the spine curvature points to the vertical plane

	Measurements of the C7/T1 point			Measurements of the L5/S1 point			Measurements of the maximum point of the kyphosis curvature			Measurements of the maximum point of the lordosis curvature		
Subject	1 test	2 test	?	1 test	2 test	?	1 test	2 test	?	1 test	2 test	?
1	155	159	-4	155	155	0	125	125	0	165	168	-3
2	174	170	4	174	172	2	132	128	4	187	187	0
3	140	144	-4	129	131	-2	106	112	-6	138	132	6
4	174	172	2	163	165	-2	132	138	-6	185	187	-2
5	145	149	-4	126	121	5	104	106	-2	144	146	-2
6	159	157	2	129	137	-8	101	101	0	141	149	-8
7	159	163	-4	140	146	-6	107	105	2	146	146	0
8	157	149	8	140	140	0	114	112	2	149	152	-3
9	200	210	-10	144	144	0	120	122	-2	135	139	-4
10	165	168	-3	165	168	-3	147	146	1	184	180	4
X	162.8	164.1	-1.3	146.5	147.9	-1.40	118.8	119.5	-0.7	157.4	158.6	-1.2
SD	17.0	18.7	5.2	16.9	16.8	3.8	15.1	14.9	3.3	20.9	20.3	4.0
means of two tests	163.5±17.7			147.2±16.7			119.2±14.9			158.0±20.5		

Δ - difference between the tests

differences calculated for all observed points to be normally distributed (S-W = 0.92-0.96; P>0.05) and the paired t-test on the mean values yielded a non - significant result (t = -0.79-1.18; P>0.05). The correlation between the differences and the mean scores ranged from r = 0.14 to r = 0.48 but non- significant (P>0.05). The calculated statistics indicated to the satisfied conditions for the limits of agreement analysis. Consequently, as the mean of difference for the point C/T1 was 1.30 mm and SD 5.2 mm, the limits of agreement were 1.30 mm ±1.96x5.2 or 1.30 mm ±10.2 mm. Expressed as a proportion of the average scores over two tests (163.5 mm), this represented a change of 6.2%. The disagreements between test-retest values of the other measured points did not exceed 6.2%.

Table 2
Limits of agreement statistics for test - retest data

Points of Measurements	Shapiro-Wilks statistic P>0.05	Paired t-test t value P>0.05	Correlation coefficient	Limits of agreement	Percent of change
C7/T1	0.92	-0.79	0.48	1.3±10.2 mm	6.2
Max point of kyphosis curvature	0.92	-0.66	0.14	0.7±6.5 mm	5.5
L5/S1	0.96	-1.18	-0.36	1.4±7.4 mm	5.1
Max point of lordosis curvature	0.95	-0.95	-0.43	1.2±7.8 mm	4.9

Fig. 3 displays differences between the measurements of the lumbarsacrum angle obtained by inclinometer and calculated from the contourograph (y axis) vs the mean value of these two methods. The mean value of the lumbarsacrum angle was 19.2°±7.6. The value of the lumbarsacrum angle estimated by the inclinometer ranged from 3° above to 3° below the value obtained by the calculated angle from the recorded contourograph. The limits of agreement statistics were as follows: S-W = 0.89; P>0.05, paired t-test t = 1.63; P>0.05, and the correlation between the differences and mean scores was -0.24; P>0.05. The differences between the values recorded by two methods did not exceed 15.6%.

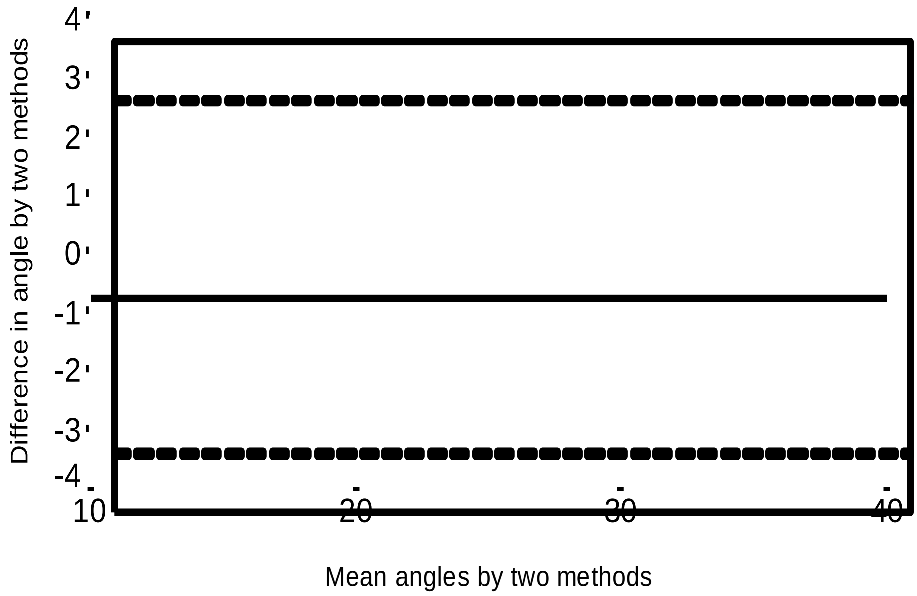

Fig. 3
Differences between the measurements of the lumbarsacrum angle obtained by inclinometer and calculated from the contourograph

Discussion

The amount of the disagreement between the test-retest measurements for the four points of spinal curvature analysed by the limits of agreement statistics that provide a more complete appraisal of repeatability than the other popular reliability statistics [2,17] ranged from 4.9% to 6.2%. In order to detect a real effect of treatment procedure on the location of the certain point of the spine curvature the difference between the pre and post treatment values must be at least 9 mm, except for the spinous process of the C/T1 vertebra, where it must be of 12 mm.

The agreement between the lumbarsacrum angle calculated from the spine contourograph and measured with inclinometer was estimated also by the LoA statistics. The disagreement between these values obtained by two different methods did not exceed 15.6%. It is consistent with the results of the test-retest measurements of the angles calculated by the tangent method from the contourograph of the spine obtained with the flexible curve that was 16% [19]. It allows to estimate the measurements of the angles from the contourograph recorded with the designed instrument to be valid at least as much as the angle measurements from the contourograph obtained with the flexible curve.

The lack of the flexible curve as noted by the authors [19] is that the excessive soft tissue could interfere with proper moulding of the flexible curve to the midline contour of the subjects. This kind of the measurement error is exclusive while using the presented instrument. Additionally, this instrument is free from disadvantages, typical for the inclinometer in recording the angles of the spine curvature, which are associated with the surface anatomy problems, identifying the reference point of measuring, the inaccurate positioning of the instrument over the required bony landmarks, and in holding the instrument in the certain position.

The video rasterstereography technique [13] which involves a three - dimensional analysis of shape of the back is also free from the above mentioned disadvantages but allows additionally to employ it in the evaluation of scoliosis. However, as noted by Haid *et al.* [13] the evaluation of spine, in median sagittal plane alone often suffices for preventive medical purposes. The contourographs recorded by this instrument help not only the rehabilitation professionals but also the patients to make easily the visual comparison of the shape of spine before and after the treatment procedure. Also, the instrument is suitable to test the possible changes in the shape of spine, which may occur in sport events, where the physical load on vertebral column is extensive.

Therefore, the constructed instrument may be considered for use as one of the alternative tools for the evaluation of the shape of the spine.

In conclusion, the designed instrument is acceptable for recording the contourograph of the spine curvature and is one of the sensitive measures to compare the changes occurred due to the different treatment procedure of the spine curvature. The designed instrument is easy to manage and the measurement procedure requires little time.

In conclusion, the results of this study indicated to the validity of the instrument for recording the contour of the spine curvature. The use of designed instrument allows to compare the changes occurred due to the different treatment procedure of the spine curvature. However, to draw more general conclusion there is need for further research evaluating the validity of measurements among different population. Also the comparison of the results recorded by the designed instrument with another one with no contact instrument to the body surface will be useful.

References

1. Adams M.A., P.Dolan, C.Marx, W.C.Hutton (1986) An electronic inclinometer technique for measuring lumbar curvature. *Clin.Biomech.* 1:130-134

2. Atkinson G. (1995) A comparison of statistical methods for assessing measurement repeatability in ergonomics research. In: G.Atkinson and T.Reilly (eds.) Sport, Leisure and Ergonomic. E.& F.N. Spoon, London, pp 218-222

3. Bland J.M., D.G.Altman (1986) Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1:307-310

4. Boone D.C., S.P.Azen, C-M.Lin, C.Spence, C.Baron, L.Lee (1978) Reliability of goniometer measurement. *Phys.Ther.* 58:1355-1360

5. Bridger R.S., D.Wilkinson, T.Van Houweninge (1989) Hip joint mobility and spinal angles in standing and in different sitting postures. *Human Factors* 31:229-241

6. Burdett R.G., K.E.Brown, M.P.Fall (1986) Reliability and validity of four instruments for measuring lumbar spine and pelvic positions. *Phys.Ther.* 66:677-684

7. Chen Y-L., Y-H.Lee (1997) A non-invasive protocol for the determination of lumacasral vertebral angle. *Clin.Biomech.* 12:185-189

8. Drerup B., B.Ellger, F.Meyer zu Bentrup, E.Hierholzer (2001) Rasterstereographische funktionsaufnahmen. Eine neue methode zur biomechaishen analyse der skelettgeometrie. *Orthopade* 30:242-250

9. Dvir Z., T.Prushansky (2000) Reproducibility and instrument validity of a new ultrasonography-based system for measuring cervical spine kinematics. *Clin.Biomech.* 15:658-664

10. Gill K., M.H.Krag, G.B.Johnson, L.D.Haugh, M.H.Pope (1988) Repeatability of four clinical methods for assessment of lumbar spinal motion. *Spine* 13:50-53

11. Gilliam J., D.Brunt, M.MacMillan, R.E.Kinard, W.J.Montgomery (1994) Relationship of the pelvic angle to the sacral angle: measurement of clinical reliability and validity. *J.Orthop.Sports Phys.Ther.* 20:193-199

12. Hackenberg L., U.Liljenqvist, E.Hierholzer, H.Halm (2000) Rasterstereografische oberelachenvermessung idiopathischer skoliosen nach VDS. *Z.Orthop.Ihre.Grenzgeb.* (Germany) 138: 353-359

13. Haid C., S.Fischler, G.Holzmyuller (1996) Feststellung der ryuckenform in der mediansagittalebene mittels neigungssensoren. *Biomed.Tech.* (Berl) 41:6 183-186

14. Lamb K. (1998) Test- retest reliability in quantitative physical education research: a commentary. *Eur.Phys.Educ.Rev.* 4:145-152

15. Liljenqvist U., H.Halm, E.Hierholzer, B.Drerup, M.Weiland (1998) Die dreidimensionale oberflachenvermessung von wirbelsaulenderformitaten anhand der videorastersteregraphie. *Z.Orthop.Ihre.Grenzgeb.* (Germany) 136:57-64

16. Mauritzson L., J.Ilves, G.Benoni, K.Lindstrom, S.Willner (1991) Two dimensional airborne ultrasound real-time linear array scanner-applied to screening for scoliosis. *Ultrasound Med.Biol.* (England) 17:519-528

17. Ottenbacher K.J., S.D.Tomchek. (1994) Measurement variation in method comparison studies: an empirical examination. *Arch.Phys.Med.Rehabil.* 75:505-512

18. Toppenberg R.M., M.I.Bullock (1986) The interrelation of spinal curves, pelvic tilt and muscle lengths in adolescent female. *Aust.J.Physiother.* 32:6-12

19.Youdas J.W., V.J. Suman, T.R.Garret (1995) Reliability of measurements of lumbar spine sagittal mobility obtained with the flexible curve. *J.Orthop.Sports Phys.Ther.* 21: 13-20

Accepted for publication 31.01.2002

Acknowledgments

The author thanks Paul Narusberg for the construction of the instrument