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ORIGINAL ARTICLE

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Weight distribution in the sitting position in patients with paralytic scoliosis: pre- and postoperative evaluation

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Abstract Patients with paralytic scoliosis spend most of their time in the sitting position. The spinal deformity, pelvic obliquity and uneven weight distribution on the seating surface necessitates frequent seating adaptations in the wheelchair. In this prospective study, 45 wheelchair-bound patients were evaluated preoperatively and 43 postoperatively. The pre- and postoperative evaluation was done by an independent observer. Surgical correction was performed between 1993 and 1996. Assessments included sitting balance on a box; number of seating supports in the wheelchair; weight distribution on the seating surface, measured with a computerized EMED system; Cobb angle; hip dislocation; mediolateral translation of T1 and of the apex vertebra with reference to a perpendicular line drawn upwards from the spinal process of S1; and pelvic obliquity from a line drawn between the most proximal points in the iliac crests. X-rays for the measurement of Cobb angle and pelvic obliquity were performed in sitting position. Reference values for normal weight distribution on the seating surface were obtained for 27 normal subjects and revealed a mean value of 59% of weight supported on one side. A stepwise regression analysis on the preoperative results showed that pelvic obliquity and thoracolumbar/lumbar spinal imbalance explained weight distribution on the seating surface (R^2=0.45). There were significant improvements in all variables except in sitting balance and imbalance of T1, 1 year postoperatively. When dividing the material into two subgroups, the results showed no significant difference in any of the assessed parameters of the scoliosis, pelvic obliquity, or sitting position between individuals with even (50–59% on one side) and those with uneven (60–100% on one side) weight distribution postoperatively. The results of the assessment showed a significant improvement after surgical correction, but the majority still had pelvic obliquity and uneven weight distribution in a sitting position. The weight distribution on the seating surface preoperatively was explained by thoracolumbar/lumbar spinal imbalance and pelvic obliquity, with R^2 = 0.45. There were no significant differences in any variables in comparisons between individuals with even weight distribution and those with uneven weight distribution. For the group with even weight distribution, however, the mean pelvic obliquity was 6° and in the group with uneven weight distribution the mean pelvic obliquity was 12°. Attention to seating surface and adjustment of seating position is needed for patients with paralytic scoliosis.

Keywords Paralytic scoliosis · Weight distribution · Pelvic obliquity

Introduction

Shook and Lubicky [17] stated that evaluation and management of pelvic obliquity in neuromuscular patients is both challenging and important, and that more research is needed into how different factors influence the sitting position.

A satisfactory sitting position is vital, as patients with paralytic scoliosis are commonly wheelchair users and spend most of their time sitting, despite poor sitting balance. These patients can be spastic or floppy, with a tendency to slide out of their wheelchairs, which leads to the need for a continuous process of constructing new seating adaptations to provide support.

In a previous prospective study by Larsson et al. [10], patients with paralytic scoliosis were found to have maintained or improved their sitting balance 1 year after spinal fusion. Time used for resting and the number of seating supports in the wheelchair were significantly reduced. However, with respect to a better sitting position that enables the individual to spend more time sitting in the wheelchair, there may be a risk of pressure sores, especially for individuals with low or no sensibility. Weight distribution on the seating surface was improved but still uneven according to results from normal cases measured by Smith and Emans [18]. They measured weight distribution in the sitting position with a computerized pressure plate system in a study conducted in normal subjects and patients with idiopathic and neurological scoliosis (n=100). They reported that normal cases placed up to 60% of their weight on one side, and asymmetric weight distribution was consequently defined as greater than 60% of the pressure on one side.

Osebold et al. [14] reported in a retrospective study that 4 of 17 patients with paralytic scoliosis had pressure sores over the ischium on the low side of the tilted pelvis before surgical correction. Uneven weight bearing can lead to painful sitting for patients with intact sensation and to pressure sores for patients who are without protective sensation.

Harms [8] pointed out that the key to promoting good sitting posture lies in controlling pelvic positioning and the related shape of the lumbar spine.

Dubousset [7] classified pelvic obliquity into “regular pelvic obliquity”, where the pelvis is going in the same direction as the spine, and “opposite pelvic obliquity”, where the pelvis tilts in the opposite direction from the spine. Dubousset [7] also described pelvic obliquity as the primary cause of the spinal deformity and stated that most spinal deformities can cause pelvic obliquity, as well as curves above the lumbosacral junction, depending on their size, stiffness, inability to create a compensatory lumbosacral curve below the junctions, tightness of the iliolumbar ligaments, or asymmetric function of the erector spinae muscles. While a number of authors [2, 3, 4, 5, 6, 9, 14, 17, 18] have assessed sitting problems in patients with paralytic scoliosis, the factors that explain weight distribution on the seating surface have not been described.

Aim of the study

The aim of this study was to evaluate the effect of surgical treatment on the sitting position in wheelchair-bound patients with paralytic scoliosis with an independent ability to sit, and to investigate what factors explain weight distribution on the seating surface.

Materials and methods

Assessments

Samuelsson et al. [16] suggested a set of instruments for clinical evaluation after surgery in neuromuscular scoliosis, to be combined with conventional measurements. We used the same approach in combination with some additional measures. In this study, the following data were collected:

- Descriptive data: age, gender and diagnosis.
- Number of seating supports in the wheelchair.
- Sitting ability, defined as sitting balance and rated from no ability (1 point) to full ability to sit (7 points), with the patient sitting on a box with the feet supported (Mulcahy et al. [13]); levels of 2–7 points were used in the present study.
- Weight distribution across the seating surface measured with a computerized EMED system (Novel, Munich, Germany): force (N), pressure (N/cm^2), and area (cm^2). In this study the distribution of pressure and area between the two ischial seating surfaces was used. The EMED system divides the sitting position into two portions, with the weight distribution calculated as percentages. Weight distribution was measured in a sitting position with the feet supported, the knees at a 90° angle, and a 90° angle between the thighs and trunk.
- The Cobb angle was measured in the coronal plane, and in addition, an assessment of C- or S-curved scoliosis and hip dislocation was carried out.
- The mediolateral translation of the apex vertebra was measured in millimetres as the orthogonal distance from the spinal process of the apex vertebra to a perpendicular line drawn upwards from the spinal process of S1.
- The mediolateral translation of the first thoracic vertebra was measured in millimetres as the distance between T1 and a perpendicular line drawn upwards from the spinal process of S1.
- Pelvic obliquity was measured according to Osebold et al. [14] as the angle between a line connecting the most proximal points on the iliac crests and a line, intersecting this line, drawn parallel to the lower end of the roentgenogram.

X-rays of Cobb angle and pelvic obliquity were performed in sitting position. Pre- and postoperative evaluation was done by an independent observer.

Reference material

To get reference values for weight distribution on the seating surface, a group of normal subjects was used. Sixteen girls and 11 boys, who were senior level students in an elementary school, were included. The mean age was 14.7 years (range 14–16). The subjects were inspected by an orthopaedist to exclude anyone with spinal deformities.

The mean value for the percentage of weight supported by the side of the seating surface carrying the larger load in the group of normal subjects was 59% (range 50–86%), and there was a slight tendency to put more weight on the left side. Those values were in line with the results of Smith and Emans [18]. In our study, the mean value for the percentage of area placed on the side of the seating surface carrying the greatest area was 54% (range 50–81%) and the Pearson correlation between weight distribution and area distribution in percentage terms was r=0.73 (P=0.0001).

The test-retest reliability of the computerized EMED system for measurement of weight distribution placed on one side of the seating surface (N/cm^2) and of area (cm^2) was performed in 14 individuals with a mean age of 19.6 years (range 9.7–37.4). Ten patients with spinal deformities and four normal subjects had measurements performed twice during the same day by the same therapist. The intraclass correlation coefficient (ICC) for weight distribution (N/cm^2) was 0.99, with a mean difference of –0.2 (range from –4 to 6), and the ICC value for area (cm^2) was 0.97, with a mean difference of –0.7 (range from –10 to 5).

Patients

Forty-five of 69 consecutive patients with paralytic scoliosis, preoperatively evaluated between 1993 and 1996 in connection with spinal surgery at the University Hospital in Linköping, were included. Posterior segmental instrumentation with sublaminar wires, hooks, and screws were used for all patients. The instrumentation and fusion extended to the pelvis, according to Galveston**,** in all patients with pelvic obliquity of 10° and above. In 19 patients an anterior instrumentation with Zielke apparatus was combined with posterior segmental instrumentation. The inclusion criteria were ability to sit during evaluation of pelvic obliquity and being a wheelchair user. The excluded patients were 11 who were ambulatory and 13 who were without the ability to sit independently. In the end, 45 patients were included preoperatively and 43 in the postoperative analyses. One patient refused to participate in the postoperative investigation, and one patient did not participate due to a long travel distance. The included patients represented 13 different diagnoses (Table 1) and their mean age was 16 years (range 8–43), with a median age of 14 (with 11 in the first quartile and 16 in the third). There were 33 females and 12 males, of whom 20 had persistent skin discoloration. A thoracic mediolateral translation was found in eight patients and a thoracolumbar/lumbar translation in 37 patients. Thirty-five patients had C-curved scoliosis, most with regular pelvic obliquity, according to the Dubousset classification [7], and ten had S-curved scoliosis with opposite pelvic obliquity, as described by the same author. Fifteen patients had hip dislocations, six on the left side and three on the right side, and six had bilateral hip dislocations.

Table 1 Number of patients and their diagnoses (n=45)

N	Diagnosis
15	Myelomeningocele
8	Cerebral palsy
7	Rett’s syndrome
4	Spinal muscular atrophy
2	Myopathies
2	Spinal cord injury
1	Poliomyelitis
1	Central core disease
1	Chromosonal abnormalities
1	Encephalopathy
1	Guillian-Barré syndrome
1	Microcephaly
1	Muscle dystrophy Duchenne

Statistical methods

Wilcoxon’s signed rank test was used in the analyses of nonparametric data to detect any differences pre- and postoperatively. Paired t-tests were performed to analyse parametric data pre- and postoperatively, and unpaired t-tests were used to analyse differences between groups.

Multiple and stepwise regression analyses were used to identify factors that explained weight distribution on the seating surface. Pearson’s correlation test was used for the bivariate analysis. In the analysis of data for test-retest reliability, the ICC was used.

Results

When the pre- and postoperative results were compared (Table 2) 1 year postoperatively, there were significant improvements in all variables except sitting balance and

Table 2 Pre- and postoperative data on 43 patients with paralytic scoliosis ($q1$, $q3$ first and third quartiles)

	Preoperative		Postoperative		*P*-value
	Mean	(Range)	Mean	(Range)	
Angle of scoliosis (degrees)	81	(30–145)	35	(2–95)	0.0001
Mediolat transl T1 (mm)	31	(0–140)	28	(0–83)	0.8000
Mediolat transl thoracic curve[a] (mm)	66	(11–117)	31	(0–82)	0.0001
Mediolat transl thoracolumbar/lumbar curve[a] (mm)	71	(15–120)	35	(0–82)	0.0006
Pelvic obliquity (degrees)	19	(2–44)	10	(0–36)	0.0001
Weight distribution when sitting on one seating surface (%)	86	(54–100)	73	(50–100)	0.0005
Area distribution when sitting on one seating surface (%)	80	(50–100)	68	(50–100)	0.008
	Median	(q1–q3)	Median	(q1–q3)	*P*-value
Sitting balance (2–7)	5	(3–6)	5	(3–6)	0.3881
Seating supports in wheelchair (n)	1	(0–3)	1	(0–2)	0.0057

[a]Mediolateral translation of the apex vertebra measured as the orthogonal distance from the spinal process of the apex vertebra to a perpendicular line drawn upwards from the spinal process of S1

Table 3 Postoperative results for groups divided into patients with even (50–59%) and those with uneven (60–100%) weight distribution across the seating surface

	Even weight distribution (n=12)		Uneven weight distribution (n=31)		P-value
	Mean	(Range)	Mean	(Range)	
Angle of scoliosis (degrees)	35	(14–95)	35	(2–75)	0.9747
Mediolat transl T1 (mm)	21	(0–53)	32	(2–83)	0.1447
Mediolat transl thoracic curve (mm)	30	(3–82)	32	(0–72)	0.7972
Mediolat transl thoracolumbar/lumbar curve (mm)	34	(0–82)	36	(7–81)	0.8738
Pelvic obliquity (degrees)	6	(0–13)	12	(0–36)	0.0619
Weight distribution when sitting on one seating surface (%)	53	(50–58)	81	(62–100)	
Area distribution when sitting on one seating surface (%)	59	(52–90)	72	(50–100)	
	Median	(q1–q3)	median	(q1–q3)	P-value
Sitting balance (2–7)	5	(3–7)	5	(4–7)	0.7198
Seating supports in wheelchair (n)	1	(0–2)	1	(0–1)	0.5675

Table 4 The side of hip dislocation in relation to the side of greatest weight bearing, the side of pelvic obliquity, and the side of thoracolumbar/lumbar translation

No. of patient	Hip dislocation	Greatest weight bearing	Low side of pelvic obliquity	Thoracolumbar/ lumbar translation
1	Left	Right	Left	Left
2	Right	Right	Right	–
3	Right	Left	Left	Left
4	Left	Right	Right	Right
5	Left	Right	Right	Right
6	Left	Right	Right	Right
7	Left	Right	Right	Right
8	Right	Left	Left	Left
9	Left	Right	Right	Right

mediolateral imbalance of T1. When the material was grouped according to how weight was distributed between the left and right sides of the seating surface postoperatively, there were no significant differences in any variables (Table 3) between those with even weight distribution and those with uneven weight distribution. In the group of patients with even weight distribution, the mean pelvic obliquity was 6° and in the group with uneven weight distribution the mean pelvic obliquity was 12° (Table 3).

Patients without hip dislocation (n=30) preoperatively showed no differences in any other variables when compared with the group with unilateral hip dislocations (n=9). There was an inverse correlation between the side of hip dislocation (n=9) and the following variables: side of weight distribution, side of thoracolumbar/lumbar medial translation, and side of pelvic obliquity (Table 4).

A stepwise regression analysis on the preoperative data showed that the variables pelvic obliquity and thoracolumbar/lumbar spinal imbalance explained weight distribution across the seating surface. The adjusted R^2 for the regression model was 0.45, indicating that these two independent variables explained 45% of the weight distribution on one seating surface. The β value, or standardized regression coefficient for pelvic obliquity, was 0.42, and for the thoracolumbar/lumbar spinal imbalance the β value was 0.41.

Among the surgically corrected patients who had more than 60% of their weight distributed on one side, one patient with myelomeningocele had persistent discoloration of skin on the side that the pelvis was lower and the greater part of the weight was supported. All of the fused patients had received further adjustments to the anti-pressure seats in their wheelchairs postoperatively.

Discussion

In a study by Smith and Emans [18], it was argued that the most important factors for patients with paralytic scoliosis were the pathological changes in sitting pattern associated with pelvic obliquity and increasing Cobb and spino-pelvic angles. The present study demonstrated preoperative abnormalities in sitting position associated with spino-pelvic imbalance, with an uneven weight distribution on the seating surface. The factors that explained weight distribution on the seating surface were thoracolumbar/lumbar spinal imbalance and pelvic obliquity. Thoracolumbar spinal imbalance is generally expected to be more prominent in patients with C-curved scoliosis than in patients with S-curved scoliosis.

Letts et al. [11], Lonstein and Beck [12], and Samuelsson and Eklöf [15] found in studies of patients with paralytic scoliosis and windblown hip syndrome that the pelvis was part of the curve, and the curve was convex away from the high side of the oblique pelvis. Letts et al. [11] pointed out that a majority of the patients (17/22) had the dislocated hip and high side of the oblique pelvis away from the convex curvature. On the other hand, Lonstein and Beck [12] observed a tendency for the majority of patients (12/20) to have the hip dislocation to the right side when the pelvis was high on the left side. In the present study, the majority of patients had the convexity of scoliosis and greater weight bearing to the right side, with the high side of the pelvis and the hip dislocation to the left side. These findings are in accordance with Letts et al. [11].

The Cobb angle and pelvic obliquity were measured in the coronal plane and not in the sagittal plane, because in this study we were interested in how the sitting position was distributed between the two ischial tuberosities by the centre of gravity.

The postoperative results demonstrated that the Cobb angle of the spine and the spino-pelvic angle were improved, resulting in less need for seating supports in the wheelchair. Equipment showed good test-retest reliability, and our reference population gave the same weight distribution as previously reported by Smith and Emans [18]. Although weight distribution across the seating surface was improved, it was still uneven compared to the reference values, with 31 of the 43 patients on a group level still showing uneven weight distribution. The distribution of area on one seating surface was also significantly improved and more evenly distributed compared to preoperatively, but was still uneven according to the reference value found in the present study.

Shook and Lubicky [17] pointed out that the goal of surgical treatment is a spine as straight as possible over a pelvis that is as level as possible. They also stated that pelvic obliquity is associated with uneven weight bearing in the sitting position, and that an uneven pelvis leads to an unstable base for the spine. One of our patients with spinal cord injury and pressure sores on the lower side of his pelvis (preoperatively the pelvic obliquity was 15°) had been severely limited in his daily life activities because of the need to rest to relieve the pressure. After surgical correction and fusion, the pelvis is level and he can sit for the whole day and is studying on a dental technician course. However, the results also demonstrate that the majority of patients still suffered from pelvic obliquity, which indicates how difficult it is to totally correct pelvic obliquity with surgery.

Dubousset [7] stated that regular pelvic obliquity occurs in the frontal plane if the pelvic tilt is in the same direction as the lumbar spine. It is obvious that pelvic obliquity and thoracolumbar/lumbar imbalance are not the only factors explaining weight distribution; in fact Dubousset [7] meant that causes of pelvic obliquity are numerous. Postoperatively we could not find any factors explaining weight distribution. Most of the patients retained a mediolateral imbalance postoperatively, and the effect of surgery with a fused spine diminishes the possibility of compensating the sitting position by active trunk movements. In spite of that, we noticed patients' attempts to compensate the fused spine with neck and head movements. In addition, spinal alignment has to be analysed to make sure the patient has a straight, balanced sitting position with postural control. Asher [1] defined spinal alignment as "proper positioning of parts in relation to one another", measured by a line drawn between T1 and S1 in the sitting position.

Shook and Lubicky [17] also argued that the patient can be a "functional quadriplegic", requiring the use of hands or elbows to support the spine in the sitting position.

Nevertheless the interventions as a whole should make it easier for the patient to free his/her hands and arms for purposeful tasks in everyday daily life.

Therefore, it is of great importance for wheelchair-bound patients to achieve a proper sitting position and also to unload the lower part of pelvic obliquity to avoid pressure sores.

Conclusion

This study demonstrated that, after surgical correction, assessment results were improved for measurements of angle, translation, and pelvic obliquity, but the majority of patients still showed pelvic obliquity and uneven weight distribution in the sitting position.

There were no significant differences in any variables in comparisons between those with even weight distribution and those with uneven weight distribution; however, for the group with even weight distribution, the mean pelvic obliquity was 6° and for the group with uneven weight distribution the mean pelvic obliquity was 12°.

The weight distribution on the seating surface preoperatively was explained by thoracolumbar/lumbar spinal imbalance and pelvic obliquity, with R^2=0.45.

There is a need to pay additional attention to the seating surface and adjustment of seating position in paralytic scoliosis.

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