Thoracic Suspension: Quantitative Effects upon Seating Pressure and Posture

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Summary

Seating pressure in 10 subjects using a thoracic suspension orthosis was studied quantitatively. Anterior, posterior, and ischial pressures were measured bilaterally both unsuspended and during a 90 to 120 minute interval while suspended.

Significant decreases in seating pressure were noted following suspension, with a mean decrease of 59.8%. Significant changes in lateral support were noted with suspension, as was a reduction in both the absolute pressure and relative distribution of pressure to the ischial areas. Relative redistribution of pressure in the anterior-posterior direction was related to leg support condition. All subjects who presented with pressure sores healed subsequent to thoracic suspension. Those with spinal curvature showed a 10 to 20 degree correction immediately following suspension. This correction generally was not maintained, however, in a temporal analysis. The data indicates that thoracic suspension can effectively reduce seating pressure and alter lateral posture, while leg support condition has a greater effect upon anterior-posterior pressure distribution. The use of a seat cushion to prevent subject swinging while suspended did not adversely affect the overall suspended pressures in this study, although the subjects without seat cushions showed lower overall suspended pressures.

Key words: *Thoracic suspension orthosis; Seating pressure; Scoliosis; Myelomeningocele.*

Introduction

Patients who are anesthetic below the waist suffer from pressure sores as a result of prolonged sitting, and scoliosis due to a lack of spinal support. These problems were first addressed by Siebens *et al.* (1972), when he studied the effects of rib suspension devices on relieving those complications of the patients' neurologic deficits. In this study, 50 of the 52 subjects showed improvement. Drennan *et al.* (1979), reported on the application of thoracic suspension and the Newington protocol for its use in 64 patients using a modification of Siebens'

original instrumentation. In this study, all but 5 subjects showed improvement. Both groups indicated that thoracic suspension reduced the weight borne by the lower spine through a tractive axial force resulting from the weight of that portion of the body weight below the level of suspension. Pressure on the ischial tuberosities was thus reduced.

The purpose of this study was to evaluate the effects of thoracic suspension upon seating pressure and posture during a 90 to 120 minute test period.

Patients and methods

The study group consisted of 10 compliant patients, 5 males and 5 females. Subject background information is provided in Table I.

Table I Demographic Data

AGE (year-month)	WEIGHT (Kg)	HEIGHT (cm)	DIAGNOSIS	FUNCTIONAL	
				MOTOR LEVEL	INDICATION FOR TSO
19-3	236	145	MYELOYDYSPLASIA	T10	PRESSURE SORES
15-10	200	168	traumatic paraplegia	L2	PRESSURE SORES
15-4	83	102	MYELOYDYSPLASIA	T12	SCOLIOSIS
14-5	187	124	MYELOYDYSPLASIA	T12	PRESSURE SORES
12-4	148	135	MYELOYDYSPLASIA	L3	SCOLIOSIS
9-8	146	112	MYELOYDYSPLASIA	T12	SCOLIOSIS
8-9	128	117	MYELOYDYSPLASIA	L3	PRESSURE SORES
7-7	104	112	MYELOYDYSPLASIA	T12	SCOLIOSIS
6-9	82	112	MYELOYDYSPLASIA	T4	SCOLIOSIS
2-3	57	81	MYELOYDYSPLASIA	T12	SCOLIOSIS

The thoracic suspension orthosis used in this study was a custom moulded thoraco-lumbo-sacral orthosis. Spools for suspending the TSO from hangers on the wheelchair rear uprights were attached to the jacket sides, Figure 1. Vertical adjustment of the wheelchair hangers permitted the amount of weight carried by the jacket and the resulting distractive force to be varied. Contact between the subject and wheelchair was thus present at the spools, posterior jacket surface, buttocks, thighs, feet and arms. Subject's buttock height was adjusted to be approximately 1 cm above the seat. Clinically this was accomplished by passing a 1 cm thick object between the buttocks and seat interface. Though it may seem that a 1 cm gap would provide zero pressure, the effect of normal slippage, as subjects settled vertically in their jackets, produced contact and resulting pressure. Some contact was desirable as it prevented free swinging of the subject and resulted in greater compliance. Foot rests were adjusted to provide support in the suspended position. Clinically this was accomplished by raising the foot rests an amount comparable to the increase in height with suspension.

Figure 1 Wheelchair application of the thoracic suspension orthosis (TSO).

Subjects were examined for seating pressures either immediately after their initial training period or subsequent to jacket refitting in order to estimate performance under optimal fit conditions. All of the subjects tested could tolerate suspension for a minimum of 5 hours per day.

The initial TSO training period required 3 weeks to complete. During this time, the period of suspension was gradually increased on a daily basis. In addition, skin tolerance was increased by applying alcohol to problem areas. Erythema was observed during the first and second weeks, but did not persist following the training period. Complaints of pain or skin abrasion were also observed only during the first few weeks. As noted by Drennan (1979), sensitivity to abrasion, heat and pressure is not necessary for safe TSO usage, if the subject is closely monitored.

To measure gluteal sitting pressure, 4 inflatable silicone envelopes were placed in a triangular pattern centered about the ischial tuberosity over each buttock, Figure 2. The silicone envelopes were attached by a thin sheet of Bioclusive transparent dressing.* Baseline pressures were recorded with the subject prone on a plinth table. A record of unsuspended pressures with the subject seated in his/her wheelchair was then obtained. Suspension was then begun for a period of 90 to 120 minutes with pressures recorded every 15 minutes. Final unsuspended and plinth table pressures were also recorded. All subjects wore shorts with no seams in the buttocks area and remained relatively motionless during the test period.

* Johnson and Johnson, New Brunswick, N.J.

Figure 2 Distribution of silicone envelopes over the gluteal surfaces.

Instrumentation

Eight flat silicone rubber envelopes with internal electrical contacts were used for pressure measurement. The envelopes were inflated with a syringe until internal and external pressures equalised, and the internal contacts separated, causing an indicator to light on the pressure readout device.* The readout device employed a solid state pressure transducer (Microswitch, Honeywell, 120 PC series) and displayed pressures in mmHg with a resolution of 0.1 mmHg. Results of a static pressure calibration of the device are illustrated in Figure 3. Accuracy was determined to be well within 1.0 mmHg.

Results

Pressure distribution

All of the tested subjects showed a substantial reduction in seating pressure with suspension. Bilaterally, the percent pressure decreased significantly, ranging from 25.6 to 90.3%, with a mean decrease of 59.8% [$p < 0.01$]. Actual pressures in the unsuspended state ranged from 24.4 to 50.8 mmHg, while the suspended values ranged from 2.6 to 30.5 mmHg.

Bilateral support measured by the large (ischial) envelopes ranged from 21.4 to 44.5% of the total pressure in the unsuspended state with a mean of 26.6%. In the suspended state, the range was significantly reduced to 4.3 to 25.6% of the total unsuspended pressure with a mean of 11.1% [$p < 0.01$]. The relative distribution of pressure with respect to the large envelopes was also significantly

* Clinical Technology Corp., Kansas City, Mo.

Figure 3 Static calibration.

reduced with suspension [$p = 0.04$]. Bilateral relative suspended pressure of the ischial envelopes ranged from 20.3 to 49.4% with a mean of 28.7%.

Lateral balance of the test subjects was investigated by comparing mean right and left pressures before and during suspension. This was expressed as the difference in percent pressure borne by the right and left sides. A positive value indicated that the greater pressure was on the left side. Unsuspended ranged from 28.4 to -11.8% with a mean of 8.0%. Suspended range was from 43.5 to -3.5% with a mean of 4.6%. Without suspension, significantly more pressure was borne by the left side [$p < 0.01$]. With suspension, the left side continued to offer greater support to a significant degree [$p < 0.01$]; however, there was a significant shift in laterality following suspension towards greater lateral balance [$p = 0.04$].

Distribution of weight in the anterior-posterior direction was measured by comparing the mean pressure distributed between the 2 posterior and 1 anterior envelopes. Percent differences were expressed as the difference between the mean anterior and posterior measurements. A positive value indicated that greater relative pressure was borne by the anterior. Unsuspended ranges were -70.0 to 72.0% for the right side and -30.8 to 60.0% for the left with respective mean values of 16.0 and 17.2%. Suspended ranges were -74.2 to 62.0% for the right side and -42.5 to 54.0% for the left with respective means of 13.2 and 15.6%. Without suspension, significantly more pressure was borne by the anterior envelope on both sides [$p < 0.01$ right, $p < 0.01$ left]. This trend remained with suspension [$p < 0.01$ right, $p < 0.01$ left]. Although suspension did reduce the relative pressure borne by the anterior envelopes bilaterally, the reduction was not significant [$p > 0.05$].

Maintenance of posture was investigated by reviewing the change in pressure with time when suspended. Mean bilateral pressures increased an average of 1.7 mmHg over the 90 to 120 minute test interval. Left and right side mean pressure increases were 2.0 and 1.3 mmHg respectively.

The group of subjects without seat cushions showed significantly higher pressures bilaterally in the unsuspended state [$p < 0.01$]. The mean bilateral pressure of this group [$N = 4$] was 43.9 mmHg, while that of the group with cushions* [$N = 6$] was 37.0 mmHg. Following suspension, the group without cushions had significantly lower bilateral pressures [$p < 0.01$]. Respective mean pressure values for the groups were 9.4 and 23.3 mmHg.

Of the 10 subjects studied in this work, 8 had vertical foot supports. The remaining 2 subjects had their legs in a horizontal position with support at the calf and did not use a seat cushion. These 2 subjects were compared to the 2 subjects also without seat cushions but with vertical foot supports. The relative percent pressure over the large (ischial) envelopes in the subjects with vertical foot supports significantly exceeded those of the group with calf supports when not suspended [$p < 0.01$]. This relationship was significantly reversed, however, following suspension [$p < 0.01$]. Respective mean percent pressures borne by the large (ischial) envelopes for the vertical and calf supported cases were 34.1 and 20.8% unsuspended and 17.9 and 22.8% suspended.

Spinal curvature

Spinal curvatures were evaluated in the short term with and without suspension. Of the 10 patients described, 2 had pre-existing spinal fusion. An additional 4 patients did not undergo X-ray studies comparing suspended to unsuspended spines and were excluded from the measurement subgroup. The remaining 4 patients demonstrated an improvement of 10 to 20 degrees in scoliosis. Two of these patients also had kyphosis and showed improvements from 50 and 65 degrees to straight spines with suspension.

Progression of spinal curvature was also reviewed for a longer period. Of the 10 patients studied, 6 had appropriate films taken at intervals over periods of 6 to 26 months. Curves in 4 of the 6 patients worsened. The respective rates of progression were: 20 to 25 deg, dextro, L1-L4, 6 months; 55 to 62 deg, dextro, T2-L5, 24 months; 22 to 30 deg, levo, T8-L1, 26 months; and 44 to 55 deg, levo, T7-L1, 12 months. In 1 patient, there was no change (16 deg dextro, T8-T12, and 18 deg, levo, L1-L5, 12 months). In 1 patient there was a measurement of improvement (47 to 40 deg, dextro, T6-L3, 8 months). Thus, application of suspension in these cases did not generally halt the progression of scoliosis. The effect upon reducing the rate of progression that would occur with another type of brace or if the condition was untreated, however, remains unclear. (Kyphosis patients treated with suspension did not have sufficient data for temporal follow up.)

Discussion

It is generally recognised that pressure is the primary cause of decubital ulcer

* Cushion type: low density polyurethane 'T-Foam', Ali-Med 1197-S, Boston, Ma.

formation. The exact mechanism for tissue damage, however, is unclear. Clinically it has been suggested that in patients without sensation, pressures above 30 to 40 mmHg for periods greater than 30 minutes should be avoided if not periodically relieved. The early work of Landis (1930) demonstrated that capillary pressure ranged between 20 and 30 mmHg. Clearly external pressure exceeding this would ultimately produce deprivation of nutriment and tissue necrosis. In our study, suspension reduced mean bilateral pressures to 9.4 mmHg overall with a mean bilateral ischial value of 2.7 mmHg. This dramatic reduction was likely responsible for the healing observed in all subjects who presented.

All of our patients tended to lean to the left side when not suspended. This imbalance improved with suspension but did not correct completely. These findings indicate that establishment of suspended posture should include consideration of lateral balance because it is directly influenced through suspension positioning.

In the investigation of anterior-posterior weight distribution, our study group showed significantly higher anterior pressures both unsuspended and suspended. The subjects with calf supports and no cushions showed significantly higher anterior envelope pressures than those without cushions and vertically supported legs, [$p < 0.01$] unsuspended and [$p = 0.03$] suspended. These findings differ from those of Bush (1969) in which distal thigh pressures of seated subjects on cushions with vertical and calf supported legs did not differ significantly. Because Bush was able to demonstrate a relationship between distal thigh pressure and cushion length, we expect that our results are related to wheelchair seat depth, an absence of cushions, and relatively proximal placement of our anterior envelopes.

In our investigation of ischial pressures secondary to leg position, we found consistently higher values in the subjects with vertically supported legs when unsuspended. This trend was reversed following suspension. In the unsuspended analysis, our findings agree with those of Bush, although in our study cushions were not used.

The analysis of suspended subjects showed that overall increases in bilateral pressure occurred. Clearly the time related pressure increases of an average 1.7 mmHg, over a 90 to 120 minute period, do not pose a significant problem.

The group of subjects without seat cushions showed significantly higher pressures than those with cushions when unsuspended. This would be anticipated and is supported by other investigations. Following suspension, however, the group without seat cushions exhibited significantly lower pressure. We attribute this to the initial adjustment session in which the suspended height was established. The subjects in our study who preferred to use seat cushions wanted contact with the cushion to prevent swinging while suspended.

Mechanically the TSO allows gravitational forces to provide axial traction. Without TSO, gravitational forces would serve to compress the spine when upright.

The effect of thoracic suspension on spinal curvature is difficult to assess primarily because of the small size of the patient subgroups and relatively brief follow-up period. In the short term analysis, a lessening of kyphosis and scoliosis was noted. The longer term analysis, however, revealed that scoliosis curvatures

were generally increasing. This limited information perhaps warrants a study of increased scale in which curvatures are monitored over a longer term.

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