行政院國家科學委員會專題研究計畫　成果報告

神經肌肉性脊柱側彎矯具之綁帶張力調整的臨床要領

計畫類別：個別型計畫
計畫編號：NSC93-2213-E-002-075-
執行期間：93 年 08 月 01 日至 94 年 12 月 31 日
執行單位：國立臺灣大學醫學工程學研究所

計畫主持人：章良渭
共同主持人：林銘川，林光華

報告類型：精簡報告
報告附件：出席國際會議研究心得報告及發表論文
處理方式：本計畫可公開查詢

中　華　民　國 95 年 1 月 9 日

Clinical Significance of Strap Tension Adjustment on Spinal Orthoses for Neuromuscular Scoliosis

神經肌肉性脊柱側彎矯具之綁帶張力調整的臨床要領

計畫編號: NSC 93-2213-E-002-075
執行期間: 93/08/01 ~ 94/12/31
主持人/執行單位: 章良渭 臺灣大學醫學院醫學工程研究所

Abstract

Background: Individuals with neuromuscular scoliosis are thought to have respiratory muscle weakness causing a restrictive pattern, abnormal compliance of the chest wall and lung, and mismatched ventilation and perfusion. Therefore, a spinal orthosis, a rigid supporting body jacket, leads to restriction of chest expansion and significant reduction in vital capacity immediately. Strap tension has an influence on pulmonary function; on the other hand, strap tension also affects the correction of spinal deformity. If the patient does not apply enough force on straps, the effective correction of spinal deformity will be reduced. The tension adjustment of straps on spinal orthoses is clinically significant for neuromuscular scoliosis. The overall effectiveness of the spinal orthosis will therefore depend on how tightly its strap is adjusted and fastened. *Objectives*: To quantify the strap tension and find an optimal value to achieve the best correction of spinal deformity but least compromise of pulmonary function. *Setting*: Orthotic services, National Rehabilitation Engineering Research Center, Taipei , Taiwan. *Participant*: A seven-year-old girl with spinal muscular atrophy, presenting a scoliotic curve. The curve was a left lumbar C curve and the apex was at L1. *Intervention*: A custom molded co-polymer anterior-opening Thoracic-Lumbar-Sacral Orthosis (TLSO) with three adjustable straps. *Optimal strap tension solution*: An objective function was chosen as the weighted sum of two indexes, i.e., an index of the pulmonary function and an index of vertebral correction. *Main Outcome Measures*: Strap tensions, slow vital capacity (SVC) for the pulmonary function index, Cobb angle and apex rotation for the vertebral correction index. *Results*: Optimal strap tensions all lie in between 60% to 70% of the tightest tension which the subject can tolerate. *Conclusions*: In the past, clinicians had no idea to adjust objectively the tightness of the straps on TLSO for individuals with neuromuscular scoliosis. This study provided a systematic approach to find an optimal strap tension where both pulmonary function and vertebral correction were taken into consideration at the same time.

摘要

脊柱側彎矯具是目前咸認對於脊柱側彎病患最普遍也最有效的非侵入式治療。除了脊柱的矯正效果之外，長期使用脊柱側彎矯具對病患肺功能的增進也有幫助。然而若是對因本身呼吸肌衰弱造成胸廓運動及換氣機制不正常的神經肌肉性脊柱側彎病人來說，脊柱側彎矯具在穿戴時，會限制原本即已孱弱的呼吸運動機制，病患馬上就會感到影響程度不一的不舒適感，進而降低穿戴脊柱側彎矯具的意願。

綁帶張力大小會左右脊柱矯正的效果。若綁帶使用不當造成張力不足，矯正的成效會大打折扣；矛盾的是太大的張力又會立即使病患的肺功能變差，加重病患的不舒適感，病患穿戴的意願也就跟著下降。本研究即是探討這幾項因素之間的關連性，我們會從量化綁帶張力開始，並且試圖從脊柱矯正、肺功能和張力之間的關係做一深究，最後將找出一組對神經肌肉性脊柱側彎病患矯正效果和肺功能都可兼顧的矯具綁帶張力，企盼能給病患更具客觀性和功能性的脊柱側彎矯具治療，藉以提升病患長期配合脊柱側彎矯具療程的意願，而能早日達成既定的矯正目標。

Introduction

Spinal orthoses may benefit patients with neuromuscular scoliosis, especially those with poor trunk control or athetosis, by improving their sitting ability, positioning, and head control, as well as stabilizing their spinal curves.1 Improved trunk support affords to better head/neck control and allows better use of upper extremities. Scoliosis curve correction was seen in ambulating patients with muscle hypotonia and short thoracolumbar/lumbar curves measuring <40° as well as in non-ambulating patients with spastic short lumbar curves.2 However, the application of spinal orthoses for the patients with neuromuscular scoliosis impacts on pulmonary function and causes some skin problems because spinal orthoses apply forces on trunk and then restrict the expansion of chest wall.3 Noble-Jamieson et al.4 studied in 40 children with neuromuscular disease, 20 of whom had scoliosis and were non-ambulant and have found that spinal bracing, a rigid supporting jacket, results in a significant reduction in mean vital capacity of 22%.

Studies have shown that the strap tension is clinically significant in the effectiveness of curve correction. It correlates to the interface pressure on the pads and the pressure exerts on the scoliotic spine resulting in curve correction.5,6 It has been a common practice that the straps be tightened as much as the patient can tolerate and it has been suggested that the strap tension be regularly and closely monitored when the spinal orthosis is applied. However, the pulmonary function has never been taken into account when the strap tension is monitored. This research further proposed that the adjustment of the strap tension is significantly important in pulmonary function management as well as curve correction, particularly for the patients with neuromuscular scoliosis. It was hypothesized that the strap tension could be adjusted according to the optimal requirement of the overall effectiveness in pulmonary function management and curve correction.

The purpose of this research was to develop an objective method of adjusting the strap tension such that the overall effectiveness of spinal orthoses on neuromuscular patients with scoliosis can be ensured.

Patient: A seven-year-old, female, 123cm and 34kg, spinal muscular atrophy, non-ambulatory patient (Figure 1).

Figure 1 Spinal orthosis provides sitting support for patient with neuromuscular scoliosis. (a) without spinal orthosis, (b) with spinal orthosis fixed by tapes when fitting, (c) with spinal orthosis fixed with Velcro straps.

Intervention: Orthotic treatment by using an anterior opening custom-made thoraco-lumbo-sacral orthoses (TLSO) (Figure 2), made of Copolymer shell and Aliplast liner.

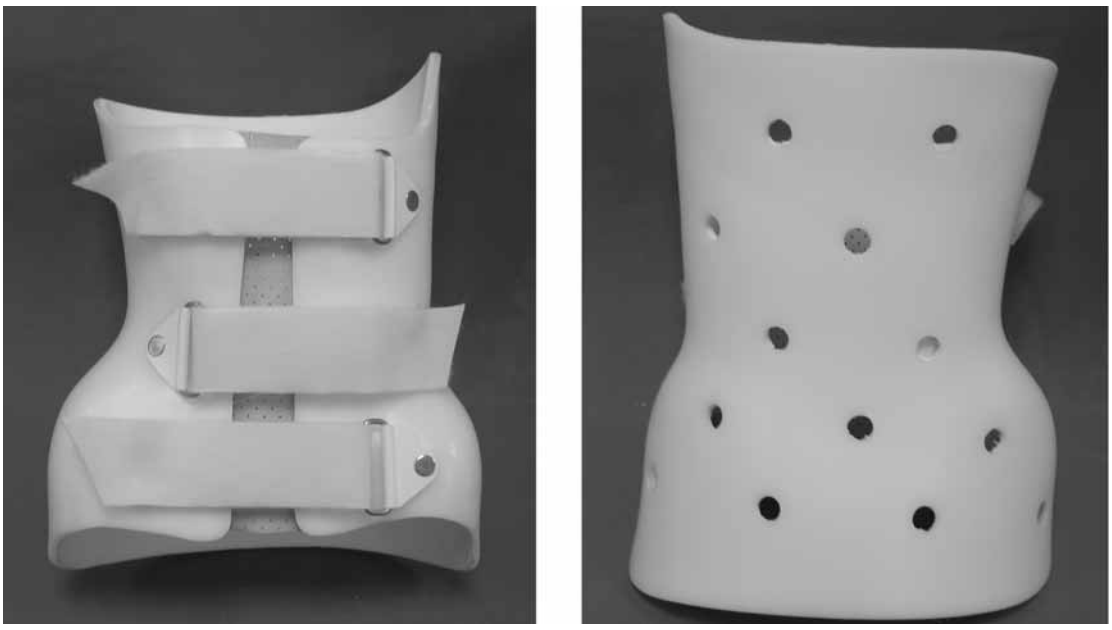

Figure 2 Total contact TLSO.

Measurements: Slow vital capacity (SVC) was measured by pulmonary function testing using a portable spirometer (Microspiro HI-601, CHEST Inc., Japan) (Figure 3). From patient's x-ray films, Cobb angles and vertebral rotation angles were measured and computed. A device with a force gage (DPX-50T, IMADA Inc., Japan) was used to measure the trap tension making sure the strap is parallel to the line of pull (Figure 4).

Figure 3 A portable spirometer.

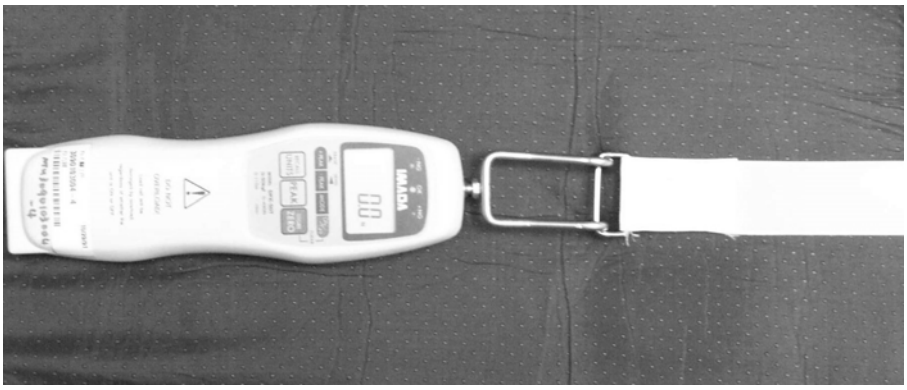

Figure 4 A measuring device for strap tension.

Figure 5 The radiographs of the subject. (a) without spinal orthosis (sagittal view), (b) without spinal orthosis, (c) with spinal orthosis and fixing the strap at T1, (d) with spinal orthosis and fixing the strap at T2, (e) with spinal orthosis and fixing the strap at T3, (f) with spinal orthosis and fixing the strap at T4.

Optimization:

The optimal strap tension can be obtained when an objective function reaches a maximum. The objective function φ in this research was defined to be

$$\varphi = w_1 P(T) + w_2 [C(T) + R(T)]$$

where

T : strap tension as a control variable

P (T): index of pulmonary function

C (T) + *R (T)*: index of vertebral correction, where *C (T)* and *R (T)* are the functions of the change of Cobb angle and vertebral rotation, respectively

w1 and *w2* : the weightings assigned for the descriptors of pulmonary function and vertebral correction, respectively. These weightings can be adjusted proportionally to the importance given for each descriptor. The sum of *w1* and *w2* is equal to 1 (100%).

Results

The patient's scoliotic curve was left lumbar C curve and the apex was L1. The tightest strap tension that she could tolerate is defined as T1, the values of which measured at the superior, middle, and inferior straps were 24.3N, 22.6N and 31.8N, respectively. T2, T3 and T4 are the tensions in order of looseness, where T4 is the loosest tension. The strap tensions are shown in Table 1. And the radiographs at different strap tensions are demonstrated in Figure 5. The normalized percentage of SVC, correction of Cobb angle and apex rotation changing with respect to strap tensions are graphed in Figures 6-8, correspondingly. The optimal strap tensions (Table 2) all lie in between T2 and T3.

Strap tensions (N)	T1	T2	T3	T4
Superior strap	24.3	17.6	11.6	9.2
Middle strap	22.6	18	13.5	9.9
Inferior strap	31.8	26.2	19.1	10.8

Table 1 The various strap tensions of three straps.

Straps *w1* / *w2*	Optimal strap tension (N) (percentage of T1)		
	Superior	Middle	Inferior
0.6 / 0.4	16.16 (66.5%)	15.94 (70.5%)	21.56 (67.8%)
0.7 / 0.3	15.05 (61.9%)	14.62 (64.7%)	20.09 (63.2%)

Table 2 Optimal strap tensions under different weightings.

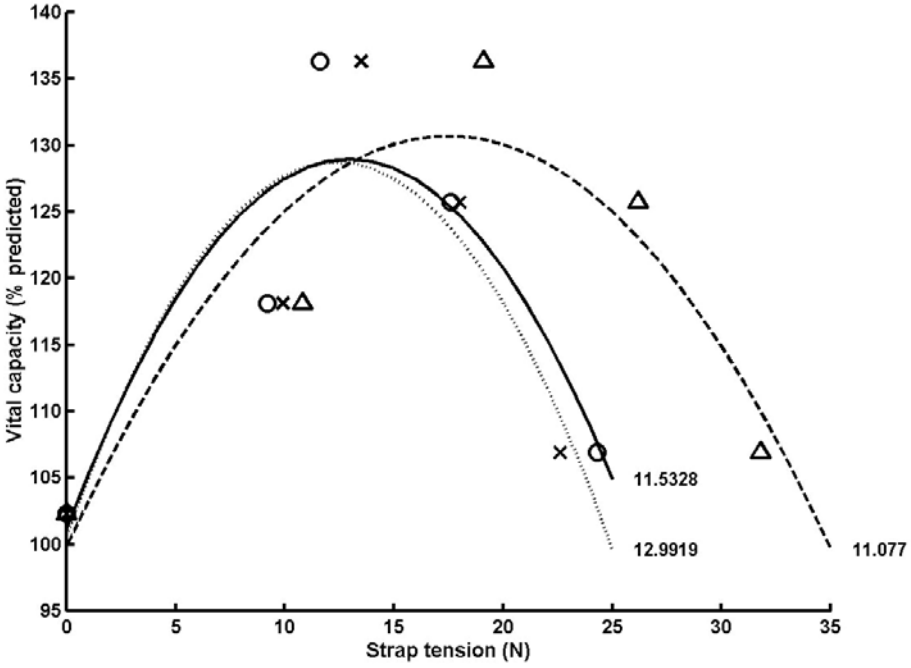

Figure 6 Change of predicted SVC at various strap tensions.

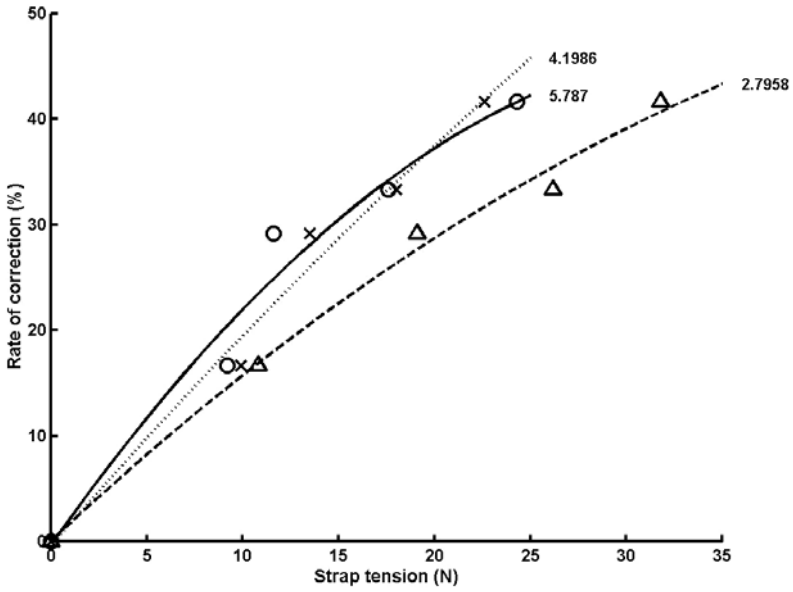

Figure 7 Change of Cobb angles at various strap tensions

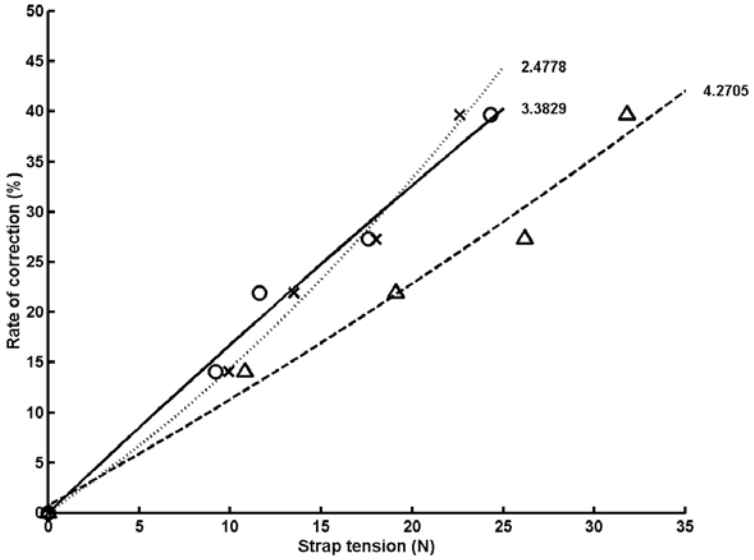

Figure 8 Change of apex rotation at various strap tensions.

Discussion

The optimization is an engineering technique that allows us to find the best solution for conflicting indexes, in our case the pulmonary function and scoliosis control. This research provides a systematic, objective way of adjusting the strap tension in orthotic treatment of neuromuscular scoliosis. It was also found that appropriate strap tension indeed was beneficial for

improvement of pulmonary function because the abnormal chest expansion would be limited and the neural load-compensatory mechanisms was induced due to the abdominal pressure provided by the spinal orthosis. Vital capacity testing is not feasible for younger patients or patients with cognitive problems and other parameters are sought in future research.

Conclusions

The pulmonary function is vital to neuromuscular patients with scoliosis and must be taken into account when orthotic treatment is considered. There exists an optimal solution for the adjustment of strap tension such that the overall effectiveness of the orthotic treatment is ensured in terms of maximizing the scoliosis control and minimizing the pulmonary compromises. This method was to reduce the subjectivity of orthotic practice and also to expand the clinical application of strap tensions to control more conflicting indexes.

References

1. Letts M, Rathbone D, Yamashita T, Nichol B, and Keeler A. Soft Boston orthosis in management of neuromuscular scoliosis: a preliminary report. Journal of Pediatric Orthopedics 1992;12(4): 470-4.

2. Olafsson Y, Saraste H, Al-Dabbagh Z. Brace treatment in neuromuscular spine deformity. Journal of Pediatric Orthopedics. 1999;19: 376-9.

3. Leopando MT, Moussavi Z, Holbrow J, Chernick V, Pasterkamp H, Rempel G. Effect of a Soft Boston Orthosis on pulmonary mechanics in severe cerebral palsy. Pediatric Pulmonology. 1999;28(1): 53-8.

4. Noble-Jamieson CM, Heckmatt JZ, Dubowitz V, Silverman M. Effects of posture and spinal bracing on respiratory function in neuromuscular disease. Archives of Disease in Childhood. 1986;61(2): 178-81.

5. Wong MS, Evans JH. Biomechanical evaluation of the Milwaukee brace. Prosthetics & Orthotics International. 1998;22(1): 54-67.

6. Wong MS, Mak AFT, Luk KD, Evans JH, Brown B. Effectiveness and biomechanics of spinal orthoses in the treatment of adolescent idiopathic scoliosis (AIS). Prosthetics & Orthotics International. 2000;24(2): 148-62.