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Case Report

Effect of the Modified 3-Dimensional Scoliosis Brace on Dynamic Force Application and its Cardio-Respiratory Functions in Adolescent Idiopathic Scoliosis (AIS)

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ABSTRACT

Background: Scoliosis bracing is the most commonly used non operative treatment plan for the AIS. This study is aimed developing an appropriate spinal orthosis with dynamic 3-D force application in comparison with Boston brace for correction and estimation of cardiorespiratory functions.

Case description and method: 3-D brace was fitted on the case according to a sub classification of the SRS guidelines. Breathe cardio-respiratory data analysis and the metabolic data analysis done through the K4B2, COSMED-Srl-Italy.

Results: The averages observed for without brace Boston and 3-D are different in this case, except for VT and O2-expenditure, where though Boston and 3-D shows significant difference with the normal

Outcomes and conclusion: This case-report indicates that dynamic 3-D orthosis can be a healthier option for AIS as compared to Boston Brace with a positive range of cardio-respiratory functions.

Keywords: 3-D brace; Human Performance; Gait Lab; Occupational health; Cardiology; Cardiac Rehabilitation; Clinical Nutrition

BACKGROUND

Scoliosis is a spinal deformity that affects three planes of the spinal axis [1]. Pain, spinal motion restriction, cardio-respiratory problems are widely observed with AIS patients who have not received any treatment. Spinal mechanics or biomechanics can better explain the cause of these symptoms [2]. Over decades and decades idiopathic scoliosis (80% to 90%) is dominating as its cause is still unknown. Rapid effects are seen in the period of adolescence [3,4]. Scoliosis Research Society (SRS) and the International Society on Scoliosis Orthopaedic Rehabilitation and Treatment (SOSOSRT) data show that the frequency of AIS is 2% to 3% in the overall population. [5,6]. Females are extensively effected as compare to male (female/male ratio is around 7:1) [7]. Various curve progression factors for the AIS are sex, age, skeletal maturity, value of cobb's angle, growth rate and growth potential [8].The treatments options for AIS are bracing and lastly surgery [9-12] and in every treatment plan the primary goal is to arrest or reduce the curve progression [13,14]. Progressive AIS curves and having cobb's angle ≤200 needs immediate treatment [15-17]. The application of corrective and supportive external forces (Orthotic treatment) supports to the trunk as well as correct the scoliosis curvature [18]. Bracing is one of the standard treatment option for the AIS over 50 years [19].

Cardio-respiratory problems are usually observed in AIS. Abnormal alignment changes of rib and vertebrae and elastic force of cardio-respiratory organs are responsible for the metabolic problems [20].

This case study shows a 17 years Indian girl diagnosed with AIS. This case study highlights the effect of orthotic treatment in terms dynamic force application (modified 3-D brace) and its cardiorespiratory functions.

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CASE DESCRIPTION AND METHOD

17 years old girl was diagnosed with AIS. The patient was having a lateral curvature with Dorso-Lumbar (D-10-L-5). Vertebral bodies are normal, appendages including pedicels are intact. Intervertebral disc spaces are maintained. Psoas shadows of both sides are normal. Both sacro-iliac joints are well outlined and normal. The patient was having pain while sitting down, while washing clothes specially after rinsing the clothes. Previously patient was used to regular Boston brace for the last 1 year. Through this application the curve progression was not increased. After 1 year we provide her the modified Boston brace that is modified 3-D brace. Study setting was at National Institute for the Locomotor Disabilities, Kolkata, India. Here we mentioned independent variable-Cobb ' s angle, Cardio respiratory functions and dependent Variables: Modified 3-D brace, Boston Brace. Data collection tool was COSMED $K4b^2$ system.

- Chief complaint: Pain and lateral curvature of spine and problem in posture.
- Trunk, Flexor 5, Extensor-5. Trunk Range of motions is in with in normal range.
- Hip (Flexor, Extensor, Abductor, Adductor, Internal rotator, External rotator), (Flexor, Extensor) and Ankle (Plantanflexor, Dorsiflexor) with normal grade. i.e, Grade 5. Hip, knee, and ankle all passive and active range of motions is normal.
- All the shoulder (Flexor, Extensor, Abductor, Adductor, Internal rotator, External rotator) elbow (Flexor, Extensor), wrist (Flexor, Extensor) of upper limb were in normal grade. i.e, Grade 5 and range of motion are also normal.
- Pain is present.
- Tenderness absent.
- Spasm absent.
- Sensation intact.
- Cobb' s angle-25 degree (thoracic curvature)
- Apex of vertebra: T12.
- Vertebra rotation is present in thoracic region:- grade -III according to Nash –Moe method
- Speech-NAD
- Hearing-NAD
- Vision-NAD
- Memory-NAD
- Coordination-NAD
- Writing-independent, reading-independent and playing.
- Running and jumping-independent.
- Prolonged sitting-independent.
- Prolonged standing-independent, squatting-independent.
- Scoliosis of the upper dorsal spine is notated with concavity to the left side.
- Bony maturity is not completed (Risser's sign-IV).
- Shoulder asymmetry, pelvic obliquity and waist asymmetry was prominent.
- No organ is missing.
- Adam test positive.
- Balance is nearby normal. (Checked through Force plate).

The modified 3-D brace (Components and Trim lines of the 3-D brace)

Modified brace was fabricated and fitted with SRS guidelines for orthotic assessment, casting, modification and clinical checkout.

Pelvic girdle: Same ass the Boston Brace. (Boston Manual-Scoliosis Research Society).

- One lateral upright: Lateral aluminum upright is placed at the concave side of the brace. It follows the mid axillary line.
- Special trims with flexible straps: connected below the apex of the curvature.
- Sternal pads attached and anterior aluminum upright for the simple reminder, placed in mid anterior pelvic girdle.

To understand the actual effectiveness of the modified 3-D brace, several cardio-respiratory silent parameters as given below were observed. Breathe cardio-respiratory data analysis and the metabolic data analysis done through the gold standard COSMED-Srl-Italy, $K4B^2$ (cardio respiratory function) after orthotic adaptation and after 6 months follow up.

We measure the O2 consumption level PaO2 PaCO2 Tidal volume Heart rate Energy cost EE/minVO2, VCO2, O2expenditure. Post data was taken in without brace, with Boston brace and with 3D brace. The patient was quite psychologically normal.

Patients have no stress, anxiety or fear. Basic input data was height and weight. Adaptability period was five minute. Data were taken at normal room-temperature while in the sitting position and 30 meter self-selected walking test.

At first, parts of the Cosmed $K4b^2$ analyzer were attached to the patient's body. Heart belt was fixed to the patient's box thorax and the $K4b^2$ unit was attached to the front of the harness. Battery was fixed at the heart belt on the subject's back.

Figure 1: Patient with K4b2 metabolic analyzer system for the cardio respiratory functions with brace.

Then the battery cable was connected to the 6V plug of the $K4b^2$ control panel. Precaution was taken so that the red plug, that repairs the plug from water or sweat drops, was on the Portable Unit side.

Then the antenna cable was connected to the Antenna plug of Portable Unit control panel. The heart frequency receiver and temperature probe cable was inserted in the HR-Temp plug placed on the control panel and the male connector of the turbine was inserted in the Turbine plug on the control panel.

After that the power supply cables, antenna and turbine on the right side of the jacket was fixed with the Velcro stripes provided in the equipment and the heart frequency probe was fixed on the left side. Every data measurement was taken three times and mean value was used for the result.

Reliability and Validity-COSMED K4b2: The K4b^2 (The gold standard with high accuracy) is the first COSMED portable system for intrapulmonary gas exchange analysis on true breath by breath basis. Be it sport Medicine, Research, Human Performance, Gait Lab, Occupational health, Cardiology, (Figure 1) Cardiac Rehabilitation, Clinical Nutrition and any application that requires the measurement of the cardio-respiratory response either in the field or in the lab, K4b^2 COSMED is used (Figure 2).

Figure 2: Patient with K4b2 metabolic analyzer system for the cardio respiratory functions without brace.

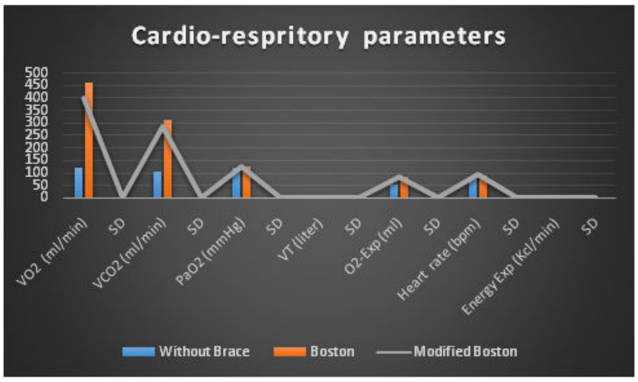

Figure 3: Here p value<0.05, hence it is significant at 5% level of significance. That means the averages for all three methods are not same, i.e. at least one of them is different from the rest. Here all the observed differences are greater than the least significant difference. So the average values for all three methods are different.

RESULTS

It was observed that after 1 year use of the Boston brace through curve correction was not observed. After six month of application of the modified 3D brace curve correction of 7 degree Cobb's angle was noticed.

Statistical analysis of observed data: Statistical analysis shown in the Table 1 indicates that the averages observed for normal Boston and 3-D are different in all cases, except for VT and O2-expenditure, where though Boston and 3-D shows significant difference with the normal, but there is no statistically significant difference between Boston and 3-D brace.

Table 1: Comparison of mean and Least Significant Difference values of cardio respiratory functions parameters in normal, with Boston brace and 3-D brace conditions.

Condition	VO2 (ml/min)	VCO2 (ml/min)	PaO2 (mmHg)	VT (liter)	O2-Exp (ml)	Heart rate (bpm)	Energy Exp (Kcl/min)
LSD	35.27787	24.579603	1.011346	0.038446	6.5152351	1.1251466	0.1663456
p value	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Without brace	123.2642 ± 21.38787	103.8362001± 17.00793	123.1147541 ± 4.062423	0.298417 ± 0.025371	53.34479381 ± 4.362835	81.55737705 ±1.500273	0.594507368 ± 0.097469
Boston	462.0005 ± 141.4525	313.1177431 ± 97.82224	126.7540984 ± 2.142084	0.511461 ± 0.159238	86.02715347 ± 26.1185	90.63934426 ± 5.391452	2.1234150508 ± 0.65409
3-D	397.8551 ± 103.1214	285.8663144 ± 67.31619	125.1147541 ± 1.808299	0.479276 ± 0.107299	82.81191954 ± 17.60203	92.31147541 ± 2.446365	1.857906884 ± 0.470888

VO2 (27.25 ml/min), VCO2 (1.64 ml/min), PaO2 (0.03 mmHg), VT (3.22 litter), O2-Exp (0.27 ml) and Energy Exp (0.27 Kcl/min) decreased in 3D brace in compression with Boston brace. But heart rate (1.68 bpm) is increased.

R.Q (Respiratory coefficient, VCO2./VO2)=0.8, Normal condition (Without brace).

R.Q (Respiratory coefficient, VCO2./VO2)=0.7, With Boston Brace.

R.Q (Respiratory coefficient, VCO2./VO2)=0.7, With 3-D Brace.

(Respiratory Exchange Ratio) RER: The ratio of CO2 Production to O2 consumption under exercise condition. An

RER>0.90 is indicative of anaerobic activity, and an RER>1.00 is indicative of severe exertion (Figure 3).

OUTCOME

The purpose of this study was to develop an appropriate spinal orthosis possibility better than the regular Boston brace in case of AIS in connection with curve correction, dynamic force application and cardio-respiratory functions.

Evidence for the modified dynamic brace.

The special trims flexible straps are applied dynamic force. Rigid concave upright and by the special trimmed with flexible straps we can apply a large or small amount of the force. Generally in underarm braces don't have the traction application. The simple reminder responsible for creating traction for dynamic elongation of the spine.

Theodoros et al. pointed out that the need of the Boston brace modification is essential according to patients need and application of dynamic force. They designed the dynamic derotation brace on the basics of the Boston brace [20].

Nguyen et al. and De La Huerta et al. expressed that the true importance of this combined curve and postural classification would become clear later when the dynamic treatment concept is explained [21,22].

Coillard et al. and Bernick et al. states that reduction of cobb's angle depends upon the changes in the compression and tensile loading (Creep force, axial traction) of the vertebral growth plates and can limit, stabilize or even reverse the vertebral deformity [23,24].

Coillard et al. pointed out that dynamic force application create a new movement strategy which becomes integrated into the brain overwriting the previous abnormal posture. The corrective movement's resultant new posture and Cobb angles are maintained post bracing with no loss of correction over time. Long term studies demonstrate extremely stable results post dynamic corrective brace treatment two years and more post bracing [25].

3-D brace can significantly increase patient's acceptance to stop curve progression without cardio-respiratory discomfort in AIS patients. Statistical analysis shows that the averages observed for normal Boston and 3-D are different in all cases, except for VT and O2-expenditure, where though regular spinal orthosis and 3-D shows significant difference with the normal, but there is no statistically significant difference between Boston and 3-D brace.

Kafer et al. experimented reduction in vital capacity in severe scoliosis which was first reported by Schneevegt in 1854, an observation confirmed subsequently by numerous investigators. Kafer described several possible mechanisms for the effects of scoliosis on lung volumes.

The patient did not complain for the any cardio-respiratory discomfort during sitting and walking with 3-D brace. Result expressed temporal improvement of Cobb's angle and cardiorespiratory parameters through some results are conflicting. Gibson, et al. suggests that an early management using orthotic brace at the beginning of the wheelchair phase before the development of scoliosis [26].

On the other hand Rideau, et al. said that progressive spinal deformities are needs the orthotic treatment [27].

Negrini et al. confirmed that that bracing in patients with AIS is effective in reducing progression and preventing surgery. In addition, combining bracing with exercises has been shown to increase treatment efficacy [28].

It is seen in 1% to 3% of the adolescent population, more commonly in girls and, as suggested by the name, has no known etiology. This definition provides a starting point for treatment decisions in the growing spine. Left untreated in the growing child, numerous studies have demonstrated the negative long-term prognosis a progressive curve fosters into adulthood, including back pain, pulmonary compromise, psychosocial effects, and even death [29-31].

Although a complete discussion of these modalities is beyond the scope of this article, convincing evidence of their effectiveness does not exist. Although Goldberg reported similar surgery rates for un-braced patients compared with braced patients [32].

CONCLUSION

3D brace is partially correct for the curve correction by use of dynamic force application in comparison to regular Boston brace. No cardio respiratory discomfort was present with the application of 3D brace. Through this 3D brace the vital capacity of lunges is not significantly improved in compared to Boston application.

Dynamic force application is the current evidence orthotic clinical practice with significant approach in the treatment of AIS. Modified 3D dynamic brace is supplemental clinically suitable in the curve correction of AIS in terms of cardio-respiratory functions.

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ETHICAL APPROVAL

Institute ethical permission has been taken for this study (Letter Number-Review letter No: IEC/1610/R and D/08/2015).

DECLARATION OF CONFLICTING INTERESTS

There is no conflict of interest in this work.

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