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Evaluation of the Immediate Effect of Trunk bracing on the Energy Expenditure of Walking in Adolescent Idiopathic Scoliosis Patients

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ABSTRACT

Background: Scoliosis is one of the musculoskeletal disorders which influences the performance of patients when walking. There is not enough information available regarding the influence of orthosis on the energy consumption of scoliotic patients while walking. Therefore, the aim of this study was to investigate the effect of orthosis on energy consumption.
Methods: This is an uncontrolled before and after study (quazi-experimental). Ten scoliotic patients and 10 normal subjects with comparable age, height and weight were recruited in this study. Energy consumption of walking was obtained from the scoliotic patients in two conditions: with and without orthosis as well as from the normal subjects without orthosis and it was evaluated using polar Electro Finland heart rate monitor. The heart rate during resting and walking and the speed of walking were the parameters used for energy consumption based on physiological cost index.
Results: The energy consumption of scoliotic subjects during walking based on PCI (physiological cost index) and THBI (total heart beat index) were higher than that of normal subjects, but the difference was not significant (P>0.05). Trunk bracing induced a little reduction of energy consumption and increased the gait efficiency of scoliotic patients.
Conclusion: The results of this research showed that there was no significant difference between the PCI and THBI of normal and scoliotic subjects. Bracing had no significant effect on gait efficiency of scoliotic patients (P>0.05).

Introduction

Scoliosis is a three dimensional deformity of the spine and ribcage [1, 2], in which there is a lateral curvature greater than 10 degrees and rotation of vertebrae around a vertical axis [3, 4]. It has been estimated that 65% of cases of scoliosis are idiopathic and 80% of patients are female [5].

Although idiopathic scoliosis has a frequency of occurrence between 1 and 4% the etiology of this pathology is still not well understood [1, 6]. In spite of the unclear origin, several possible etiological factors were introduced to this pathology such as abnormality in the central nervous system, asymmetry in paraspinal muscle activity and genetic and endocrinal factors [2, 7, 8].

Medical management of scoliosis depends on the severity of the scoliotic curvature and skeletal maturity of patient and includes maintenance procedures such as physical therapy, electrical muscle stimulation, exercise, stretching, using braces and various surgical techniques. Bracing is generally recommended for scoliotic patients with a Cobb angle of between 25 and 45 degrees, primarily in order to prevent curve progression and also with the aim of achieving some curve correction [9]. Two examples of orthoses used in this regard are Boston

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and Milwaukee which act through a three-point pressure mechanism [10, 11].

Efficient human gait is essential for performing physical activities and energy-efficient locomotion pattern results in more natural walking [12]. Some studies deal with the effect of brace treatment of scoliosis patients on gait parameters, stability and scoliosis curve modification [13-18]. However, a few studies assessed the influence of trunk bracing used in scoliotic patients on gait efficiency of scoliosis patients based on energy expenditure during walking [19, 20]. In some of the related researches it was shown that trunk bracing in normal or scoliotic subjects induced stiff gait by reducing trunk, pelvis and hip motion, in turn increasing muscular mechanical work to move the center of body mass and oxygen consumption [19, 21]. However, it is suggested that after 6 months of wearing a brace, the energy cost of walking did not change in scoliosis patients [20]. In Lindh's study (assessing gait of scoliotic patients) it was claimed that Milwaukee brace insignificantly decreased the total oxygen uptake at low walking speed and increased it at higher speed [22], while in another study it has been reported that trunk bracing has no significant effect on energy consumption of scoliotic patients [19].

In several previous studies it has been shown that the frontal pelvis and hip motions are major determinants to minimize the vertical displacement of Center Of Mass (COM) and to optimize oxygen uptake and energy consumption of walking [23, 24] so that any conditions that disrupt the vertical displacement of the COM, affect the metabolic cost of walking [25, 26]. It has also been reported that trunk, pelvis and hip frontal mobility have been reduced in idiopathic scoliosis patients so it seems that gait efficiency of these patients differ from normal subjects [26, 27]. However, in our previous research we found that there was no significant difference between energy consumption of walking between normal and scoliotic groups [28].

As mentioned above, all studies that assess energy consumption of scoliotic patients during walking used ergospirometry that works based on the subject's oxygen consumption (VO2) and there is no study in the literature regarding the effect of trunk bracing on energy consumption based on heart rate monitoring during level walking. So the aim of this study was to evaluate the energy consumption of walking in adolescent idiopathic scoliosis patients in a brace and without a brace based on heart rate monitoring. We hypothesized that using trunk bracing in scoliotic patient leads to increased energy consumption of walking.

Methods

Study Population

This is an uncontrolled before and after study (quazi-experimental).Ten scoliotic patients (8 girls and 2 boys) were recruited in this study (Table 1). Scoliosis curve was below T_4 and severity of curve varies from 24-47 degrees measured based on Cobb angle. We select the curve in this range, because the trunk bracing for scoliotic patients is used for curve severity between 25-45 degrees. 8 patients used the Boston and two other used the Milwaukee brace (Table 2). These braces were rigid thoracolumbosacral and cervicothoracolumbosacral orthoses, respectively and made by the same technical orthopedist (Figure 1). Patients were asked to participate in the study with their prescribed trunk bracing. Energy consumption of walking in two situations (with and without trunk bracing) was assessed.

Table 1: The demographic characteristics of scoliotic patients included in this study

Parameter	Scolotic patients
Age (year)	13.22±2.04
Weight (kg)	44.22±14.23
Height (cm)	161.66±14.94

Patients with leg length discrepancy higher than 1 cm, previous spinal surgical treatment, those with locomotor, neuromuscular, cardiovascular and neurological problems were excluded from this study. All subjects signed an informed consent form approved by the Isfahan University of Medical Sciences and participated freely in the study.

Protocol

The energy consumption of the subjects, while walking was evaluated using polar Electro Finland heart rate monitor (Figure 2). The heart rate during resting and walking and the walking speed were the parameters used for energy consumption based on PCI. It is determined according to the following equation (Equation1).

$$\mathrm{PCI(beats/metre)} = \frac{\text{heart rate during exercise} - \text{heart rate during resting (beats/min)}}{\text{walking speed (metre/min)}} \qquad \text{Eq.1}$$

For the energy consumption test, a Polar Accurex Plus heart rate monitor was used (Polar® Accurex Plus, Polar Electro Oy, Finland). This system is also known as Polar electro, Finland and consists of a transmitter embedded in an electrode belt (Figure 1). The receiver and recorder are located in a specially designed wrist watch. The belt has two electrodes that are covered by rubber and is worn around the chest below the nipple line. The collected heart rate was transmitted to the wrist watch with the help of electromagnetic waves. The data were collected by a receiver in a wrist watch with 5 second intervals. The Polar interface Plus was used to transmit the collected data from the wrist watch to a personal computer. The accuracy of this system in collecting the heart rate is claimed to be ±1 beats per minute. According to the results of the various studies carried out, PCI is an easy to use, valid and reliable measure of energy expenditure and it can be used to analyze the efficiency of any orthoses and assistive devices [29, 30].

The reliability of PCI according to the result of the work carried out by Jaiyesimi and Fashakin is acceptable [30]. The other parameter used in this study was THBI [31].

A 22.04 meter tract with an 8 shape figure was measured out in the lab. The figure of eight is common in the literature for evaluation of energy consumption during

Table 2: scoliotic patients' information

Subject NO.	Gender	Cobb angle/side	Cobb level	Compensatory curve	Etiology	Prescribed orthotic device	Duration of orthosis use
1	Female	37- Right	T4-T11	No	Idiopathic	Milwaukee brace	3 months
2	Female	33- Left	T12-L4	No	Idiopathic	Boston brace	3 months
3	Female	24-Left	T12-L4	No	Idiopathic	Boston brace	5 months
4	Female	45-Right	T7-L1	No	Idiopathic	Boston brace	10 months
5	Female	37-Right	T11-L3	No	Idiopathic	Boston brace	3 months
6	Female	35-Right	T7-T11	Yes, Left T11-L3/ 47 degrees	Idiopathic	Boston brace	12 months
7	Female	25-Left	T2-T8	Yes, Right T9-L3/ 35 degrees	Idiopathic	Boston brace	11 months
8	Female	35-Left	T3-T7	Yes, Right T8-L3/25 degrees	Idiopathic	Milwaukee brace	5 years
9	Male	30-Left	T12-L4	No	Idiopathic	Boston brace	10months
10	Male	37-Left	T10-L4	No	Idiopathic	Boston brace	12 months

Figure 1: Boston brace

Figure 2: Polar heart rate monitoring system

walking. Walking along this figure enabled the subjects to have a steady walking speed during walking and the effects of the dominate limb was diminished.

Walking speed and total heart beat number were also used to calculate the total heart beat index (equation2).

$$\mathrm{THBI} = \frac{(\text{total heartbeats during exercise period})}{\text{total distance traveled}\,(\mathrm{m})}$$

Eq.2

Test Procedure

The subjects were asked to walk wearing the same shoes during each of the tests. In order to reduce the fatigue effects, randomization between conditions (with and without brace) was performed. The subjects were asked not to eat, drink coffee or tea at least two hours before the test. The electrodes of polar heart rate monitor were moistened with water and its straps were adjusted according to the participant's size to obtain a snug fit.

It should be mentioned that during the tests the temperature and humidity of the environment remained constant. The test was done according to the following procedure:

Heart rate monitor was worn by the subject.

Five minutes resting heart rate was collected.

Standing up and then remaining in this position for two minutes was done.

Ten minutes of walking with a self-selected walking speed around a path in the shape of a 22.04 meter figure of eight, during which further data was collected.

Five minutes of resting during which data was collected.

After finishing the test, the chest strap and wrist watch were removed and the data sent to a personal computer by using Polar interface Plus. The mean values of the heart rate from the first to 4^{th} minute and from the 18^{th} to 21^{st} were used for measuring the resting heart rate. The mean value of heart rate during walking was obtained by averaging the heart rate between the 4^{th} and 7^{th} minute of walking.

Statistical Analysis

The normal distribution of the parameters was tested by Shapiro –Wilk test. The influence of wearing orthosis on the aforementioned parameters was evaluated by use of paired samples T-test with a significant point as 0.05.

Results

The mean value of physiological cost index, speed and total heart beat index during walking are shown in Table 3. It can be seen that the energy consumption of scolitic patients during walking in an in-brace situation based on PCI and THBI was lower than that of an out brace situation. But the difference was not significant (P=0.746, 0.291).

Table 3: The energy consumption analysis parameters of normal and scoliotic subject

Condition	Scoliotic patients with trunk bracing	Scoliotic patients without trunk bracing	P value
PCI (beat/meter)	0.368±0.154	0.381±0.106	0.746
THBI (beat/meter)	1.906±0.892	2.127±0.789	0.291
Speed (meter/min)	66.729±23.202	62.443±11.819	0.462

Discussion

This study aimed to observe the immediate effect of bracing on the energy consumption of adolescent idiopathic scoliosis patients while walking. Measuring the energy expenditure whilst walking is considered as a standard method to assess functional abilities as it has been used in a lot of research studies [29, 32]. Total heart beat index is readily available for assessing the energy consumption of walking during steady and unsteady conditions [31]. Unfortunately there was not enough evidence to show the influence of trunk bracing on energy consumption of scoliotic patients based on monitoring the heartbeat. Therefore, the aim of this research was to find the difference between energy consumption of scoliotic patients in 'in brace and out brace situations' by calculating the PCI and THBI.

According to biomechanical concepts, the movements of the various body segments are integrated during walking to decrease energy consumption and to increase the mechanical efficiency of locomotion. Inman described the importance of the pelvic motions in the frontal and horizontal planes during walking [33]. He claimed that pelvic rotation in the horizontal plane reduces the fall of the center of gravity with each step and pelvic tilt lessens the rise of it during the rolling of a trunk over the stance limb. It has also been reported that pelvis and hip frontal motions are major determinants in minimizing the vertical displacement of center of body mass and optimizing energy consumption during walking [23, 24]. It seems that disruption of vertical displacement of center of mass influences the muscles mechanical work and energy expenditure during walking. Therefore, it is expected that a spinal lateral curvature changes the center of mass position and affects the gait pattern and gait efficiency,such that, Mauhadens et al [34] showed that, in scoliotic patients hip and pelvis frontal motions and transversal hip motions significantly decreased while activation timing of bilateral lumbopelvic muscles increased, compared to normal subjects so oxygen uptake and energy consumption increased in this population. However, based on the results of our previous study, the PCI and THB of scoliotic patients were more than normal subjects in level walking however it was not significant. It seems that the scoliosis curve did not alter the position of the center of body mass [28]. In some of the related researches it was shown that very short term trunk bracing limited the trunk, hip and pelvis motions and induced stiffened gait pattern, and in turn increased the muscular mechanical work to move the center of body mass [19, 21]. Such stiffened gait pattern is also observed in untreated adolescent idiopathic scoliosis patients including similar restriction of trunk, pelvis and hip motion which influence walking efficiency [34]. In this research it has been shown that Boston and Milwaukee braces did not significantly affect energy expenditure of walking. It may be related to this concept that these orthoses did not significantly reduce the body segment motions. It has also been reported that short term trunk bracing has no significant effect on EMG activity of lumbopelvic muscles, muscular mechanical work and energy consumption during walking.

As can be seen from Table 2, the walking speed of scoliotic patients was influenced when the brace was worn. It also revealed that physiological cost index decreased by using orthosis, however it was not significant. So by comparing the PCI and walking speed of scoliotic patients in the two conditions (with and without orthosis) it may be concluded that cardiopulmonary function of patients was not influenced by orthosis, as the heart rate, during walking did not possibly change significantly in the two conditions.

This research study has some limitations which need to be acknowledged, including the number of the subjects, which was small and the type of TLSO used which was different (Boston and Milwaukee braces were used). Therefore, it is recommended that the same research be done on a larger number of subjects and by using one type of trunk orthoses.

Conclusion

Based on the results of this study it can be concluded that trunk bracing insignificantly induced a small reduction in energy consumption but increased the gait efficiency of scoliotic patients.

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Conflict of interest: None declared.

References

1. Roubal P, Freeman D, Placzek J. Costs and Effectiveness of Scoliosis Screening. Physiotherapy 1999;85:259-68.
2. Burwell R, Cole A, Cook T, Grivas T, Kiel A, Moulton A. Pathogenesis of idiopathic scoliosis, The Nottingham concept. Acta Orthop Belg. 1991;58:33-58.
3. Stokes IA, Gardner-Morse M. Analysis of the interaction between vertebral lateral deviation and axial rotation in scoliosis. J Biomech. 1991;24(8):753-9.
4. Bruyneel AV, Chavet P, Bollini G, Allard P, Berton E, Mesure S. Dynamical asymmetries in idiopathic scoliosis during forward and lateral initiation step. Eur Spine J. 2009;18(2):188-95.
5. Naumovich SS, Molotkov Iu N. [Incidence of scoliosis among preschool children]. Ortop Travmatol Protez. 1973;34(10):79-81.
6. Gelalis I, Ristanis S, Nikolopoulos A, Politis A, Rigas C, Xenakis T. Loading rate patterns in scoliotic children during gait: the impact of the schoolbag carriage and the importance of its position. Eur Spine J. 2012;21(10):1936-41.
7. Nachemson A, Nordwall A. Effectiveness of preoperative Cotrel traction for correction of idiopathic scoliosis. J Bone Joint Surg Am. 1977;59(4):504-8.
8. Reuber M, Schultz A, McNeill T, Spencer D. Trunk muscle myoelectric activities in idiopathic scoliosis. Spine. 1983;8(5):447-56.
9. Brox JI, Lange JE, Gunderson RB, Steen H. Good brace compliance reduced curve progression and surgical rates in patients with idiopathic scoliosis. Eur Spine J. 2012;21(10):1957-63.
10. Grivas TB, Rodopoulos GI, Bardakos NV. Night-time braces for treatment of adolescent idiopathic scoliosis. Disabil Rehabil Assist Technol. 2008;3(3):120-9.
11. Blount WP, Schmidt AC, Keever ED, Leonard ET. The Milwaukee brace in the operative treatment of scoliosis. J Bone Joint Surg Am. 1958;40-A(3):511-25.

12. Park JH, Choi M. Generation of an optimal gait trajectory for biped robots using a genetic algorithm. JSME. 2004;47(2):715-21.
13. Chow DH, Leung DS, Holmes AD. The effects of load carriage and bracing on the balance of schoolgirls with adolescent idiopathic scoliosis. Eur Spine J. 2007;16(9):1351-8.
14. Wong MS, Cheng CY, Ng BK, Lam TP, Sin SW, Lee-Shum LF, et al. The effect of rigid versus flexible spinal orthosis on the gait pattern of patients with adolescent idiopathic scoliosis. Gait Posture. 2008;27(2):189-95.
15. De Gauzy JS, Domenech P, Dupui P, Montoya R, Cahuzac JP. Effect of bracing on postural balance in idiopathic scoliosis. Stud Health Technol Inform. 2002;88:239-40.
16. Sadeghi H, Allard P, Barbier F, Gatto L, Chavet P, Rivard CH, et al. Bracing has no effect on standing balance in females with adolescent idiopathic scoliosis. Med Sci Monit. 2008;14(6):CR293-8.
17. Guth V, Abbink F, Gotze HG, Heinrichs W. Investigation of gait of patients with idiopathic scoliosis and the influence of the Milwaukee brace on gait (author's transl)]. Z Orthop Ihre Grenzgeb. 1978;116(5):631-40.
18. Labelle H, Dansereau J, Bellefleur C, Poitras B. Three-dimensional effect of the Boston brace on the thoracic spine and rib cage. Spine. 1996;21(1):59-64.
19. Mahaudens P, Banse X, Mousny M, Raison M, Detrembleur C. Very short-term effect of brace wearing on gait in adolescent idiopathic scoliosis girls. Eur Spine J. 2013;22(11):2399-406.
20. Mahaudens P, Raison M, Banse X, Mousny M, Detrembleur C. Effect of long-term orthotic treatment on gait biomechanics in adolescent idiopathic scoliosis. Spine J. 2014;14(8):1510-9.
21. Mahaudens P, Banse X, Detrembleur C. Effects of short-term brace wearing on the pendulum-like mechanism of walking in healthy subjects. Gait Posture. 2008;28(4):703-7.
22. Lindh M. Energy expenditure during walking in patients with scoliosis. The effect of the Milwaukee brace. Spine. 1978;3(4):313-8.
23. Della Croce U, Riley PO, Lelas JL, Kerrigan DC. A refined view of the determinants of gait. Gait Posture. 2001;14(2):79-84.
24. Kerrigan DC, Thirunarayan MA, Sheffler LR, Ribaudo TA, Corcoran PJ. A tool to assess biomechanical gait efficiency; a preliminary clinical study. Am J Phys Med Rehabil. 1996;75(1):3-8.
25. Detrembleur C, Vanmarsenille JM, De Cuyper F, Dierick F. Relationship between energy cost, gait speed, vertical displacement of centre of body mass and efficiency of pendulum-like mechanism in unilateral amputee gait. Gait Posture. 2005;21(3):333-40.
26. Lejeune TM, Willems PA, Heglund NC. Mechanics and energetics of human locomotion on sand. J Exp Biol. 1998;201(Pt 13):2071-80.
27. Karimi MT, Borojeni MK. Evaluation of the Immediate Effect of Bracing on Gait Symmetry, Lower-Limb Kinematics, and Trunk and Pelvic Motion during Level Walking in Adolescents with Idiopathic Scoliosis. JPO. 2017;29(4):183-9.
28. Karimi M, Etemadifar M. Evaluation of the energy expenditure during walking in adolescent idiopathic scoliosis patients. JPSR. 2015;4(3):59-65.
29. Nene AV, Jennings SJ. Physiological cost index of paraplegic locomotion using the ORLAU ParaWalker. Paraplegia. 1992;30(4):246-52.
30. Jaiyesimi AO, Fashakin OG. Reliability of physiological cost index measurements. Afr J Med Med Sci. 2007;36(3):229-34.
31. Hood VL, Granat MH, Maxwell DJ, Hasler JP. A new method of using heart rate to represent energy expenditure: the Total Heart Beat Index. Arch Phys Med Rehabil. 2002;83(9):1266-73.
32. Yang C-C, Hsu Y-L. A review of accelerometry-based wearable motion detectors for physical activity monitoring. Sensors. 2010;10(8):7772-88.
33. Inman VT. Human locomotion. Can Med Assoc J. 1966;94(20):1047.
34. Mahaudens P, Detrembleur C, Mousny M, Banse X. Gait in adolescent idiopathic scoliosis: energy cost analysis. Eur Spine J. 2009;18(8):1160-8.