BRACE IMPACT ON FOOT STATICS, IN ADOLESCENT SCOLIOSIS

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Abstract. *Aim of the study is to highlight the relationship between the symmetry of the spine and the kinematics of the lower limbs in 10 adolescents (boys 40%, girls 60%), aged between 11-15 years (mean age 13.70 years, ±1.27 years); diagnosed with idiopathic scoliosis. Subjects were evaluated clinically, radiological and biomechanically by analysing the lower limb load distribution at the plantar level during walking without brace (Ev1) and with brace (Ev2) using RSScan pressure platform. Plantar Pressure (N/cm2) for ForeFoot (FF), MidFoot (MF), HeelMedial (HM), HeelLateral (HL) were analysed between left foot (LF) and right foot (RF).*
The average pressures on the LF in Ev1 is 17.73 (N/cm2), and pressure load distributions is as follows: FF 64,9%, MF 3.7%, HL 13.1%, HM 18.3%. At the level of the RF, the average pressure is 15.25 (N/cm2), load distributions is as follows: FF 64.9%, MF 2.5%, HL 15.7%, HM 14.2%. Plantar pressure distribution left/right show a higher pressure on LF HM area 4% and in RF FF area 4%.For the Ev2 on the LF the average pressure is 22.83 (N/cm2), and pressure loads distributions is: FF 67%, MF 5%, HL 13%, HM 16%. At the level of the RF, the average pressure is 19.40 (N/cm2), pressure loads distributions is: FF 65.7%, MF 4.7%, HL 14.9%, HM 14.6%. It is notice a higher pressure on LF MH area 2% and in right FF area 2%. Scoliosis has an impact on the foot static; the brace can modify posture and also plantar pressure distributions. Wearing customized corrective orthoses may be beneficial, in the sense of creating a proprioceptive type of intervention that can contribute to increased foot balance and postural control, however, further studies are needed.
Keywords*: scoliosis, bracing, baropodometry, plantar pressure load, scoliotic gait;*

Introduction

Idiopathic scoliosis (IS) is a three-dimensional complex deformity, defined as frontal plane deviation with or without axial rotation of the spine. Deviations greater than 10° lead to the radiological diagnosis of scoliosis, (Addai et al., 2020). The deformity can be divided into congenital, idiopathic and neuromuscular, of which idiopathic is the most common (approximately 80%). Among the idiopathic types, the most common is adolescent scoliosis, which affects individuals during the growth period from 10 to 18 years, being more common in women.
The prevalence of IS in children of 10–17 years is approximately 1 to 3% (Zheng et al., 2017; Yılmaz et al., 2020). In the early stages, is difficult to detect because there are no obvious symptoms, but the condition can worsen rapidly during the adolescent growth.
The etiology being uncertain, we find studies that demonstrate it is multifactorial, with hypotheses ranging from genetic and hormonal influences, changes in the nervous system and poor postural control that will changes cartilage tissue and intervertebral discs, abnormalities in the growth of bones and the spine, or also changes of biomechanics or in the length of the paraspinal muscles. (Burwell et al., 2012; Diab et al., 2012).

The risk of progression is correlated with the size of the initial curve and the remaining "bone" growth (Lenz et al., 2021). Scoliotic curves below 30º at skeletal maturity are less likely to progress into adulthood (Lee et al., 2012), Cobb angles greater than 30º have negative consequences like spinal cord compression and limb paralysis (Negrini et al., 2015), or can impair cardiopulmonary function and eventually lead to respiratory failure (Weinstein et al., 2003).

General principles of therapy

Treatment of adolescent idiopathic scoliosis includes observation/monitoring, physical therapy, orthosis and surgery (is broadly divided into conservative and surgical approaches, applied in ***mono-, duble or multipletherapy.***
The "International Society for Scoliosis Orthopaedics and Rehabilitation - SOSORT" recommends kinetic monotherapy to reduce orthotic device dependence or dual therapy to control progression and prevent surgery in IS.
Monotherapy can include physical therapy or orthotic recommended in mild idiopathic scoliosis.
Scoliosis-specific physical therapy as ***monotherapy*** for adolescent IS should include exercises for the following: 3D self-correction,

stabilization of corrected posture, subject education, and training for activities of daily living (Negrini et al., 2018), but despite the therapy evolved the effectiveness of exercise treatment remains controversial (Schreiber et al., 2015; Schreiber et al. al., 2016; Kwan et al., 2017; Aktan et al., 2021. Romberg et al. (2022) shows that early-onset scoliosis subjects on long-term orthotic monotherapy have significantly better trunk muscle endurance and strength.

A ***double therapy***, which adds orthoses to the previous one, is recommended for moderate to severe idiopathic scoliosis (Negrini et al., 2018; Gao et al., 2019), with better results in idiopathic scoliosis in adolescents with curves between 25-40 degrees (Gao et al., 2019). Some study demonstrated that this combination have improve Cobb angle, respiratory parameters, and back muscle strength (Gao et al., 2019), or in the resistance parameter for the trunk muscles (Marchese et al., 2024).

Orthoses and bracing

Most frequently used in the therapy of IS, the orthotic treatment is a conservative method (Weinstein et al., 2013; Havey et al., 2016), although different types and designs of orthotic devices are available, the general purpose of these devices is to limit the curve's advancement (Havey et al., 2016). although is a static intervention, orthotic therapy is recommended to prevent deformity progression in adolescents if they have a Cobb angle between 20° – 45° (Negrini et al., 2015). Studies report availability and use in the treatment of adolescent idiopathic scoliosis of multiple types of ~~thoracolumbosacral~~ orthosis both in terms of design, materials and treatment protocol, but all of them work according to the ***principle of the three-point pressure system*** to correct the spine from the outside (Negrini et al., 2016).

The use of static foot orthoses has a limited effect on improving spine deformity for IS, but effectively improves gait biomechanics (Li et al., 2023) or improve and compensate unequal length of lower limb biomechanics, adjusting the abnormal posture of the human body, dispersing plantar pressure and regulating gait. Bracing is viewed with skepticism in view of potential side effects such as restriction of movement, stiffness of the brace as it is believed that it could decrease the strength of the main muscles and ultimately the development of maximal bone mass (Falk et al., 2015). The benefit of braces in IS increases with the number of hours of use, according to Weinstein et al. (2013) those who have worn the orthotic for more than 13 hours a day demonstrate a success rate of 90% or higher. However, so far these suspicions seem unfounded, recently Takasaki et al. (2017) analysis show no adverse effects the impact of continuous use over a period of 6 months of a lumbosacral orthosis for musculoskeletal conditions.

Plantar pressure platforms in scoliosis evaluation and management

Adolescents with IS do not only have spine deformities but often present a pelvic tilt and rotation, pes planus, pes cavus, developmental asymmetries and biomechanical imbalances of the lower limbs (Yan et al., 2018; Fei et al., 2018). Also, it seem that due to the restrictive nature of the orthotic due to the continuous pressure on the trunk during long-term use and the restriction of mobility, brace can affect the biomechanics of the lower extremities during functional activities such as standing and walking (Mahaudens et al., 2014).

Subjects with idiopathic scoliosis have asymmetric local and whole-body changes and in plantar pressure distribution. The foot plays a critical role in maintaining lower limb biomechanical function, which includes providing balance and stabilization during human locomotion (Gefen et al., 2000).

Computerized pedobarography platforms are commonly used in clinical and research settings to assess the interaction between foot biomechanics and postural stability parameters. (Mattar et al., 2015), its utility is mainly recognised for assessment and management of foot and lower limb conditions. (Deepashini et al., 2014)

IS causes also a postural instabilities in body sway and gait parameters asymmetries such as step length and stance phase time. (Mahoudens et al., 2009). Biomechanically, subjects with idiopathic scoliosis experience complex changes during walking (Smit, 2020; Pan et al., 2020), that long-term spinal orthosis (6 months) causes changes in the biomechanics of walking, increasing the range of motion for the joints like: pelvis and hip, also some improvements of the support phase (decreasing the cadence) and increasing the step length. (Mahaudens et al., 2014)

Although this biomechanical factors are "smalls" they could have a significant impact on the subject's gait, therefore it is important to evaluate also the gait biomechanical characteristics of adolescents with IS using multiple lines of evidence.

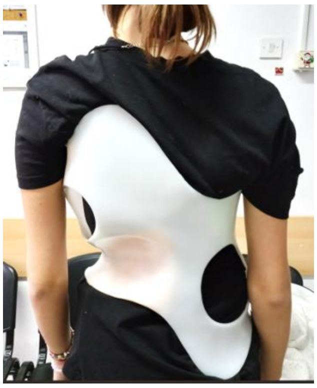

Figure 1. Rigo - Chêneau brace – (Ortoprotetica București collection)

Figure 2. X-ray before and after therapy with Rigo - Chêneau brace (Ortoprotetica București collection)

Study hypothesis

Chêneau brace that has been shown to provide a curve correction in certain cases (Cinnella et al., 2009; Zaborowska-Sapeta et al., 2011; Rigo et al., 2017), but Paolucci et al. (2013) reveals by baropodometry an improvement in lower limb loading asymmetry and postural stability during standing and walking with the Chêneau brace.

The idea of this study was to verify the gait biomechanical characteristics under the influence of an orthotic devices like the Rigo - Chêneau, a modified version of the Chêneau brace.

This corrective customized orthotic device may have the role of providing 3D corrective forces on the spine complex (bones and muscles) by placing the correction pads according to the subject spine angulations. The Rigo-Chêneau brace (Figure 1) is a type of corrective orthosis that aims to provide on the hole trunk the best 3D-corrected postural and morphological alignment, using a combination of forces applied to the surface of the trunk through specially designed pressures, facilitated by expansion or clearance of spaces (Rigo et al., 2017).

Methods.

The study included 10 adolescents (boys 40%, girls 60%), aged between 11-15 years (mean age 13.70 years, ±1.27 years); average weight 51.60kg; average height 167.10 cm; mean BMI 18.25 (kg/m2), diagnosed with idiopathic scoliosis characterized by a left-lumbar (mean Cobb angle 30.13; ± 9.37) and right-thoracic (Cobb angle 26.13; ± 10.72).

The therapy protocol was also the main inclusion criterion in the study because the subjects had to comply with the proposed therapeutic protocol applied for 3 months. The complex therapy program included:

- wearing the corset for 3 months, for 20 hours a day,
- Schroth physiotherapy sessions were performed 3 times a week,
- at home the subjects did 30 minutes of physiotherapy every day.

Subjects were evaluated clinically, radiologically and biomechanically by analyzing the behavior of the lower limb, during walking, in terms of load distribution at the plantar level.

Biomechanical evaluation was made whith ***RSScan pressure platform***, and the analyzed parameters were: Plantar Pressure (N/cm2) for the areas ForeFoot (FF), Midfoot (MF), HeelMedial (HM), HeelLateral (HL); in 2 situations WithoutBrace (Ev1) and Brace (Ev2).

The Cobb angle of each curve was measured on a standard radiograph of the anteroposterior spine (Figure 3) in the standing position. (Cobb, 1948).

Figure 3. X-ray, frontal/sagittal plane view

Figure 4. Rigo - Chêneau Brace (Ortoprotetica București collection)

Data collection was performed with the RSSCAN platform connected to computer, assessments were performed under static (standing) and dynamic (walking) conditions. All subjects were treated with the same type of thoracolumbosacral Rigo - Chêneau brace (Figure 4).

All orthotics were manufactured by the same orthotist, Ortoprotetica București. Individual molds were taken for the customization of each orthotic device, a rigid thoracolumbosacral orthosis (polyethylene, Rigo - Chêneau corset type) was manufactured, with a characteristic custom design.

All subjects were recommended to wear the orthosis for 23 hours a day, scoliosis-specific physical therapy and perform the daily kinetic program 30 minutes at home. The thoracolombosacral orthosis is designed to help restore postural balance in the spine and trunk, maintain the integrity of body balance and also the sense of body posture (proprioception), and reduce the Cobb angle, preventing progression of spine deformity.

Results

In the initial evaluation (Ev1), without brace, the average pressures on the left foot is 17.73 (N/cm2) (Table1), and pressure load distributions is as follows: Forefoot 64,9%, Midfoot 3.7%, Heel Lateral 13.1%, Heel Medial 18.3%. At the level of the right foot, the average pressure is 15.25 (N/cm2), pressure load distributions is as follows: Forefoot 64.9%, Midfoot 2.5%, Heel Lateral 15.7%, Heel Medial 14.2%. (Figure 5)

Table 1. Pressure values for the initial evaluation *(Ev1) of the subjects without brace*

Pressure Values LEFT Foot	Total Pressure [N/cm2]	*Heel Medial %*	*Heel Lateral %*	Midfoot %	Forefoot%
Total Value Pressure Left Foot Without Brace Group	177,30	18,3%	13,1%	3,7%	64,9%
AVERAGE	17,73	19,1%	13,9%	4,5%	62,5%
Pressure Values RIGHT Foot	Total Pressure [N/cm2]	*Heel Medial %*	*Heel Lateral %*	Midfoot %	Forefoot %
Total Value Pressure *Right Foot* Without Brace Group	152,50	14,2%	13,0%	3,7%	69,0%
AVERAGE	15,25	16,8%	15,7%	2,5%	64,9%

The analysis of the distribution of left/right plantar pressures shows the existence of a higher pressure on the left foot on the Medial Heel area 5% and on the right foot on the Forefoot area 4%. (Figure. 5)

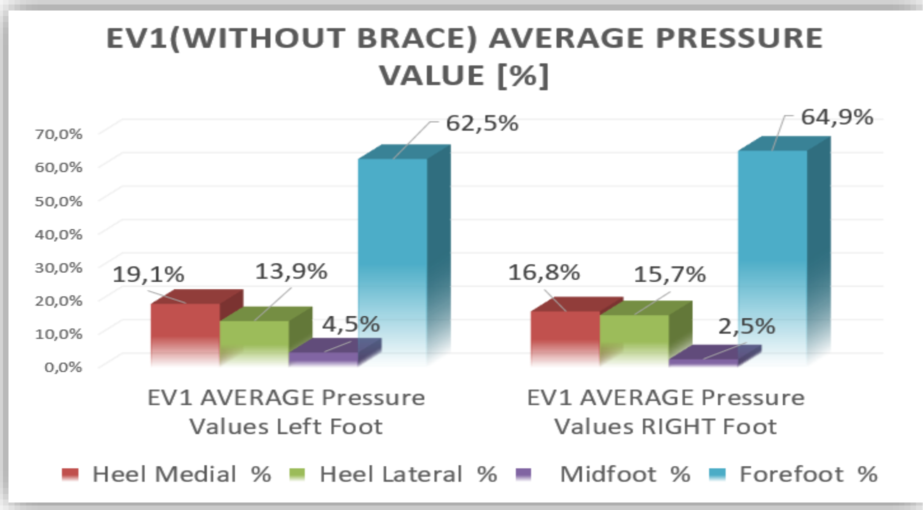

Figure 5. Plantar pressure values of subjects when subjects are not wearing the brace (Ev1)

Evaluation 2 (Ev2), in brace, on the left foot the average pressure is 22.83 (N/cm2) (Table 2), and pressure loads distributions is: Forefoot 67%, Midfoot 5%, Heel Lateral 13%, Heel Medial 16%. At the level of the right foot, the average pressure is 19.40 (N/cm2), pressure loads distributions is: Forefoot 65.7%, Midfoot 4.7%, Heel Lateral 14.9%, Heel Medial 14.6%. (Figure 6)

Table 2. Pressure values for the second evaluation *(Ev2) of the subjects with brace*

Pressure Values LEFT Foot	Total Pressure [N/cm2]	*Heel Medial %*	*Heel Lateral %*	Midfoot %	Forefoo t%
Total Value Pressure Left Foot - Brace Group	228,34	*16%*	*12%*	5%	68%
AVERAGE	22,83	*16%*	*13%*	5%	67%
Pressure Values Right Foot	Total Pressure [N/cm2]	*Heel Medial %*	*Heel Lateral %*	Midfoot %	Forefoo t %
Total Value Pressure Right Foot Brace Group	193,97	*12,7%*	*12,3%*	5,3%	69,7%
AVERAGE	19,40	*14,6%*	*14,9%*	4,7%	65,7%

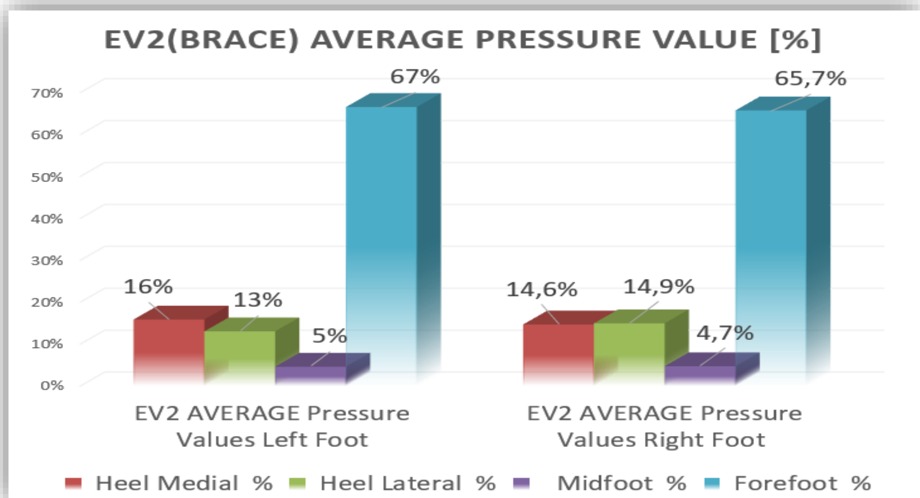

Figure 6. Subjects' plantar pressure values when subjects wearing the brace (Ev2)

The analysis of the distribution of left/right plantar pressures shows the existence of a higher pressure on the left foot on the Medial Heel area 4% and on the right foot on the Forefoot area 3%. (Figure 7). Analysis of plantar pressure distribution in scoliosis subjects (left lumbar angle, and right thoracic angle) Ev1 vs Ev2, can be found in Figure 7. In both events, we find a greater plantar pressure in left Heel Medial area and in right Forefoot area. In brace, pressures tend to equalize in all areas. The differences in mean total pressure areas (Ev1 vs Ev2) were statistically significant, p=0,005 (t-test; p<0,05)

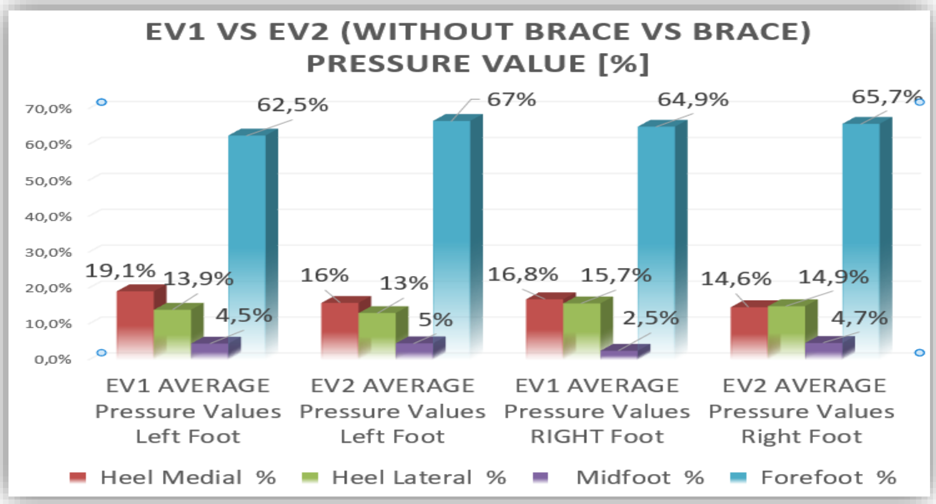

Figure 7. Dynamic pressure Ev1 vs Ev2 distribution

Discussion

This "*spine three-dimensional complex deformity*" without an identified cause is known like idiopathic scoliosis only if it definitively implies the vertebral deviation in frontal plane; the vertebral spine axial rotation is not absolutely necessary but is a factor of severity and bad prognosis also. The treatment of IS in adolescents depends on the size of the curve, which is classified according to the angulations. Values between 10º and 20º/25º are considered mild, and the indicated treatment is physical therapy or observation. Curves between 20º and 40º/45º require spinal orthosis and physiotherapeutic treatment, values above 40º/45º indicate surgical treatment.

A ***double therapy*** which adds orthoses to personalized physical therapy for moderate cases of IS can be effective especially on long term. Personalized orthoses, periodically adjusted on the evolving dimensions of the subject maybe cannot influence the scoliosis angle and vertebral rotation but the potential of improvement of postural stability (Wang, et al., 2022) is also a major undeniable key factor.

Different results have been reported regarding the effectiveness of thoracolumbosacral orthoses, such as providing stabilization, support in the symmetrical walking pattern and decreasing cadence (Rigo et al., 2013; Rigo et al., 2018). There are studies that have presented different aspects of the orthotic device in the long and short term use in adolescents years of the subjects with idiopathic scoliosis. Reguarding the thoracolombosacral brace effects reports rate brace correction and curve progression, brace influence on sagittal and coronal balance, subject preference and comfort (Cobetto et al., 2014; Cobetto et al., 2017). There are few studies evaluating postural balance and gait parameters in adolescents with IS, evaluating the immediate consequence of wearing a classic thoracolombosacral orthosis on postural balance and gait parameters. (Gür et al., 2018; Paolucci et al., 2013).

In terms of plantar pressure and postural control parameters, these studies reported that thoracolombosacral orthosis has an influence on pelvic, trunk and hip movements, and these changes lead to improved symmetrical stability in standing and walking (Song et al., 2016)

Many researchers have demonstrated the biomechanical effects of spinal orthosis, however it is essential to find out and interpret the results related to postural balance and gait parameters. The results on the functional parameters of the lower extremities can lead to the understanding of different aspects of the orthotic device.

The most acceptable approach is the application of 3D correction in the orthosis of adolescents with idiopathic scoliosis, and considering the structural properties of the spine, age of the subject, possibilities of evaluation methods and treatments. We preferred to use the Rigo Chêneau brace made by Ortoprotetica București for our study.

Conclusions

Aim of the study is to highlight the possible relationship between the symmetry of the spine and the kinematics of the lower limbs in adolescents with scoliosis undergoing orthotic treatment.

Scoliosis influences the foot static, brace causes changes at the plantar level in the sense of changing the parameters followed in this study. The analysis of the distribution between the left and right plantar pressures shows the existence of a higher pressure on the left foot on the Medial Heel area 4% and on the right foot on the Forefoot area 3% for the evaluated subject in this study.

Wearing customized foot static orthoses may have a positive influence on foot statics (increased foot balance and postural control), further studies are needed to underline the positive long term effect for subject with scoliosis, especially in adolescent where the muscular and skeletal immaturity can be a turning point factor that can be address and quantify easily.

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