Medicinski podmladak

Medical Youth

Mini review article

IDIOPATHIC SCOLIOSIS AND BALANCE

IDIOPATSKA SKOLIOZA I BALANS

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Abstract

Idiopathic scoliosis (IS) is a three-dimensional deformity of the spine and the trunk, of unknown etiology. Balance or postural control can be defined as the ability to maintain the body's line of gravity above the base of support and thus to avoid falling. Adequate balance control is not only important for maintaining postural stability, but also for safe mobility during activities of daily life. This requires efficient central processing of information coming from the visual, vestibular and somatosensory (proprioceptive) systems. The aim of this article was to review the literature about postural stability and balance performance in patients with idiopathic scoliosis. Some studies showed that people with idiopathic scoliosis have reduced postural stability, assessed with posturography, as well as proprioceptive and vestibular deficits. Two hypotheses in the literature, biomechanical and sensory integration hypotheses, tried to explain this from different points of view. The biomechanical hypothesis emphasizes biomechanical and morphological changes in IS as responsible for poorer postural stability, while the hypothesis of sensory integration points out that certain people with idiopathic scoliosis have impaired dynamic regulation of sensorimotor integration due to an inaccurate evaluation of sensory inputs. Studies that used clinical balance tests showed difficulties in mediolateral stability and dynamic proprioception in IS. Further studies on balance in this population are needed to deepen knowledge in this area.

Keywords:
scoliosis,
postural balance,
proprioception

Kovačević M. et al. MedPodml 2024, 75(3):50-55

The authors declare no conflicts of interest.

doi:10.5937/mp75-41583
Editorial board: podmladak.med.bg@gmail.com

Sažetak

Idiopatska skolioza (IS) je trodimenzionalni deformitet kičme i trupa, nepoznate etiologije. Balans ili posturalna kontrola se može definisati kao sposobnost da se linija gravitacije tela održi iznad površine oslonca i da se, samim tim, izbegne pad. Adekvatna kontrola balansa nije važna samo radi održavanja posturalne stabilnosti već i za bezbednu mobilnost tokom aktivnosti dnevnog života. Ovo zahteva efikasnu centralnu obradu informacija koje dolaze iz vizuelnog, vestibularnog i somatosenzornog (proprioceptivog) sistema. Cilj ovog članka je da prikaže podatke iz literature o posturalnoj stabilnosti i balansnim performansama kod pacijenata sa idiopatskom skoliozom. Neke studije su pokazale da osobe sa idiopatskom skoliozom imaju narušenu posturalnu stabilnost, procenjenu posturografijom, kao i proprioceptivne i vestibularne deficite. Ovo pokušavaju da objasne dve hipoteze - biomehanička hipoteza i hipoteza o senzornoj integraciji. Biomehanička hipoteza naglašava biomehaničke i morfološke promene kod IS kao odgovorne za lošiju posturalnu stabilnost, dok hipoteza o senzornoj integraciji ističe da određene osobe sa idiopatskom skoliozom imaju narušenu dinamičku regulaciju senzomotorne integracije zbog netačne procene senzornih inputa. Studije koje su koristile kliničke testove balansa su pokazale poteškoće u mediolateralnoj stabilnosti i dinamičkoj propriocepciji kod IS. Potrebna su dalja ispitivanja balansa u ovoj populaciji kako bi se produbilo znanje u ovoj oblasti.

Ključne reči:
skolioza,
posturalni balans,
propriocepcija

Introduction

Structural scoliosis is a three-dimensional deformity of the spine, which involves lateral curvature of the spine associated with rotation of the spinal column and chest, as well as a change in the sagittal profile. In 65% of cases, structural scoliosis is idiopathic scoliosis (IS), of unknown etiology (1). The diagnosis of IS is established when other possible causes such as vertebral malformations, and neuromuscular or syndromic diseases are excluded (2). The etiopathogenesis of idiopathic scoliosis is not clear, and it is considered to be multifactorial - including hormonal, biomechanical, neurosensory and genetic influences. Some authors also point out the role of the central nervous system in the pathomechanism of IS because they found proprioceptive and vestibular deficits in some of IS cases (3-5). Idiopathic scoliosis often progresses during growth, but can also remain stable or even disappear spontaneously. Idiopathic scoliosis can be infantile (occurring in the period up to 3 years of life), juvenile (occurring in the period from 5 to 8 years) and adolescent (occurring from the age of 10 until the end of growth) (6). Among them, adolescent idiopathic scoliosis (AIS) is the most common and it is estimated that 2 - 3% of adolescents have IS at the end of their growth. The prognosis of scoliosis is worse the earlier it occurs and the more cranial the curve (1).

Treatment of idiopathic scoliosis

The treatment of idiopathic scoliosis involves monitoring and physiotherapeutic scoliosis-specific exercises (PSSE) for mild curves, the use of braces for moderate curves or spinal surgery for severe curves (7). The goals of conservative treatment of idiopathic scoliosis are to stop the progression of the curve, prevent and treat pain and respiratory dysfunctions, as well as to improve the aesthetics of the trunk through postural correction (8). Firstly, PSSE implies specific exercise protocols that are individually adapted to the type of curve (7). There are different methods of PSSE, but they all have the following principles in common: three-dimensional self-correction, stabilization of the corrected posture, training in activities of daily life and patient education (8).

If scoliosis exceeds the critical limit of 30° Cobb angle at the end of growth, the risk of health and social problems in adulthood increases significantly - impaired quality of life, pain, disability, deterioration of back aesthetics, functional limitations, and sometimes respiratory problems (9, 10). In order to detect and treat idiopathic scoliosis on time, regular medical examinations of children are necessary, and according to the recommendations, it would be optimal twice a year for girls (between the age of 10 - 12 years) and once a year for boys (between the age of 13 - 14 years) (11).

Concept of balance

Although the concept of balance is often used in the medical field, there is no universally accepted definition of balance. From a biomechanical point of view, balance can be defined as the ability to maintain the body's line of gravity above the base of support and thus avoid falling. Human beings have control over balance - when the line of gravity falls outside the base of support the body is able to feel a threat to stability and use muscle activity to counteract the force of gravity and avoid falling. It is also called postural control. Postural control could thus be defined as the ability to maintain, achieve or re-establish a state of balance during any posture or activity (12). To make this possible, adequate perception of sensory information and its central processing is necessary in order to choose an adequate balance strategy and motor response (13). Postural control strategies can be reactive (compensatory) or predictive (anticipatory). Predictive strategies involve a voluntary movement, and an increase in muscle activity before an expected disturbance, while reactive strategies are movements after an unexpected disturbance. The three motor strategies for rebalancing are the ankle, hip, and stepping strategy (14).

Adequate balance control is not only important for maintaining postural stability but also for safe mobility during activities of daily life, such as getting up from a chair, standing while performing manual activities, walking, turning, etc. (15). Balance control requires efficient central processing of information coming from the visual, vestibular and somatosensory (proprioceptive) systems (16). The visual system provides information about the position and orientation of the head in relation to the environment, as well as the direction and speed of head movements. The somatosensory system, through its receptors in the muscles, tendons, joints and skin, informs about the position and movements of the body and body parts in relation to each other and in relation to the base of support. The vestibular system, thanks to its semicircular canals and otolith organs, provides information about the position and movements of the head in relation to gravity and inertial forces (17).

Balance assessment

Balance assessment can be functional, systems and quantitative (15). Functional balance tests evaluate the performance of certain motor tasks on scales or using a stopwatch, i.e. by measuring how long the subject can maintain balance in a certain position (15). Verbecque et al. divided functional balance tests into those that test stability (e.g. one leg stance, tandem stance), quasi-mobility (e.g. forward reach) and mobility (e.g. one leg hopping) (13). The advantage of these tests is that they are easy to perform, they are not expensive, they are carried out quickly and they can determine whether the balance is disturbed and whether there is a risk of falling (15). However, these tests examine one task and therefore do not reflect the entire concept of balance, so it is good to combine several different tests (13).

Systems balance assessment aims to determine the causes of balance deficits (15). An example of such a test is The Balance Evaluation System Test - BEST, which includes 6 systems of balance control: biomechanical constraints, stability limits/verticality, anticipatory postural adjustments, postural responses, sensory orientation and stability in gait (18).

Quantitative, objective assessment of balance involves the use of technologies such as static and dynamic posturography. They are used to assess postural sway and other balance parameters. Dynamic posturography involves assessment of balance in conditions of external aggravating influences such as, for example movement and oscillations of the standing surface, different visual conditions, etc. Although posturography can overcome the shortcomings of functional clinical balance tests, the high cost, space and time required for training and testing limit its wider application in the clinical setting (15).

The aim of the article

The aim of this article was to review the literature on postural stability and balance performance in patients with idiopathic scoliosis.

Postural stability in idiopathic scoliosis

Posturography assesses postural stability using force plates that measure the ground reaction forces - the sum of the pressures created by the body under the feet. The center of pressure (COP) represents the point where these pressures are concentrated. Postural stability can thus be quantified using COP parameters derived from the ground reaction forces. COP parameters that can be obtained are e.g. sway area, antero-posterior and medio-lateral displacement, etc. (19)

The meta-analysis from 2018 analyzed the studies that had been published until then about postural stability in idiopathic scoliosis, and which used posturography, i.e. quantitative assessment of COP parameters in this population compared to a control group without scoliosis. It has been shown that there is reduced postural stability in adolescent idiopathic scoliosis compared to controls. The analysis found that in scoliosis there is a shift of the COP to the right in the frontal plane and to the back in the sagittal plane (20).

In the literature, this impaired postural stability in IS is explained by two hypotheses: biomechanical and sensory integration hypothesis (**figure 1**) (20). The biomechanical hypothesis emphasizes biomechanical and

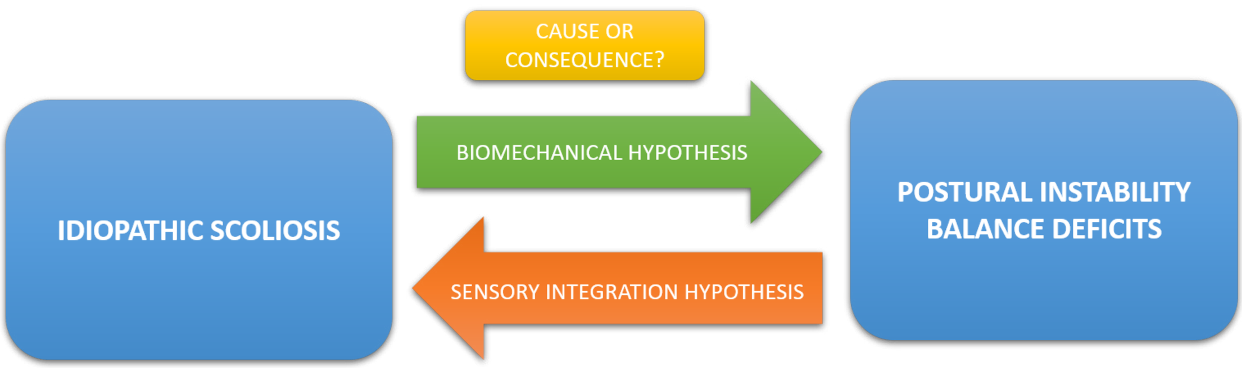

Figure 1. Scheme of the relationship between idiopathic scoliosis and balance deficits from the perspective of two hypotheses proposed in the literature.

morphological changes in IS (changes in the position of the head, shoulders, shoulder blades, pelvis in all three planes) as responsible for poorer postural stability (21). The hypothesis of sensory integration points out that certain people with idiopathic scoliosis have impaired dynamic regulation of sensorimotor integration due to an inaccurate evaluation of sensory inputs (22). This leads to balance dysfunctions due to the inability to re-establish the position of the COP towards the body's center of mass (20). The hypothesis about sensory integration and the problem of the central nervous system as responsible for postural instability in scoliosis is supported by other studies that examined proprioception, vestibular function, somatosensory evoked potentials in this population (4, 5, 22, 23).

Proprioception and vestibular function in idiopathic scoliosis

The results of meta-analysis from 2021 on proprioception in AIS show that adolescents with IS exhibit proprioceptive deficits (e.g. greater repositioning errors, higher movement detection threshold, abnormal somatosensory evoked potentials), implying possible changes in central and/or peripheral nervous system in this population. Whether proprioceptive deficits are a cause or consequence of AIS remains an open question. The researchers reasoned that if considered a causative factor, the severity of proprioceptive deficits should not be related to the size and severity of the curve. If the proprioceptive deficits are secondary to the scoliosis itself, greater curves and rates of progression should be associated with greater proprioceptive deficits (4).

Hawasli et al. analyzed the relationship between vestibular dysfunctions and idiopathic scoliosis in their review. Based on the available studies, they found level 3 - 4 clinical evidence supporting the association of these entities. However, as with proprioception, it cannot be concluded whether vestibular dysfunction plays a role in the development of IS or occurs as a consequence of individual adaptation to the curvature of the spine (5). Fewer animal studies support the hypothesis of vestibular dysfunction as an etiological factor in IS. For example, unilateral removal of the vestibular organs in a larval frog caused it to develop a scoliosis-like deformity in young adulthood (24).

Guo et al. in their study of 107 patients with AIS found abnormal somatosensory evoked potentials (SSEP) in 14.3% of subjects. This frequency is much higher compared to the prevalence of abnormal findings of 0.5% in the normal population (23). Another similar study found an even higher frequency - 27.6% of AIS patients with abnormal SSEP with a Cobb angle greater than 45° (25). These results suggest that a certain group of patients with scoliosis has impaired somatosensory function.

Factors that affect balance in idiopathic scoliosis

Researchers from Poland examined stability during unipedal support and its association with the degree of scoliosis and trunk rotation in AIS, as well as in a control group of adolescents without scoliosis. The stability was examined both with open and closed eyes, with an electronic postural station - Dalos Postural Proprioceptive System, which assessed postural control index (stability index during the eyes-open test) and proprioceptive control index (stability index during the eyes-closed test). The results showed significant differences in both indices between the study and control group, with a significantly lower proprioceptive control index in the group with idiopathic scoliosis. Based on the obtained results, the authors believe that in the process of postural control and balance maintenance, the proprioceptive system in patients with scoliosis does not play an appropriate role. This implies that in the rehabilitation programs of patients with scoliosis, attention should be paid to proprioception and that it is important for the patient, the physiotherapist and the parents to pay attention to the correct positioning of body parts during exercise, as well as to provide adequate visual feedback, e.g. by practicing in front of the mirror. Also, the authors suggest that due to impaired proprioception, people with scoliosis may be more prone to injuries, which also indicates the importance of exercises that improve joint stabilization and their inclusion in the rehabilitation program (26).

Factors that can influence static balance in AIS are the type of curve, orientation of body parts and somatotype (27). When it comes to the degree of scoliosis (Cobb angle) and its impact on postural control and balance, studies of several authors did not find significant associations (26, 28, 29). However, Haumont et al. have found, using static and dynamic posturography, that girls with AIS between 15 and 25° Cobb angle show more postural instability compared to those with a curve less than 15°. During static posturography, they showed a larger area of body sway and larger oscillations in the medio-lateral plane. During dynamic posturography, these girls found it more difficult to maintain balance and used more reactive than anticipatory strategies (16). According to Dabrowska et al. a negative correlation between the proprioceptive control index and the angle of trunk rotation measured with a scoliometer was found. Based on this, they hypothesize that exercises that reduce trunk rotation should also improve proprioception in patients with scoliosis. That is why the authors suggest examining the impact of different scoliosis treatments on proprioception (26).

Clinical assessment of balance in idiopathic scoliosis

Although posturography has proven to be valid in assessing balance, its use in clinical environments is not so frequent, so simple tests and questionnaires are used as an alternative. Some studies have shown that there is a good correlation between posturography and functional tests in assessing balance in certain groups of patients. However, not all COP parameters correlate with functional scores, suggesting that the two techniques provide information on different aspects of balance (30).

In their study, Shin and Woo used the Functional Reach Test and the Lateral Reach Test in patients with idiopathic scoliosis and controls. They found significant differences in the Lateral Reach Test between the groups, while for the Functional Reach Test they do not find a significant difference, which suggests difficulties with medio-lateral balance in scoliosis (31).

Le Berre et al. used 3 routine clinical balance tests to examine a group of adolescents with idiopathic scoliosis and a control group of adolescents without deformity. They found no difference between the groups in static balance tests (unipedal stance test and sharpened Romberg). However, they found a significant difference in the Fukuda-Utenberger test, suggesting impaired dynamic balance in individuals with scoliosis. Based on the obtained results, as well as previously conducted studies, Le Berre et al. believe that people with scoliosis have difficulties with the dynamic proprioceptive system, due to the immaturity of the CNS and poorer integration of proprioceptive afferent signals. These simple balance tests are suitable for routine clinical use and assessment of patients with IS, and the authors believe that it would be useful to examine their use as markers for scoliosis progression in longitudinal studies (29).

When it comes to the impact of scoliosis treatment on balance, few researchers have addressed this issue. Palucci et al. using stabilometry and baropodometry found that the postural instability present in AIS compared to the control group improved in some parameters when patients wore the Cheneau orthosis (32). Marin et al. found that in the self-correction position, patients with scoliosis show better parameters of postural balance compared to a relaxed standing position (33).

Conclusion

As the available studies have shown, people with idiopathic scoliosis may have impaired postural stability and balance. It remains insufficiently clear whether it is only a consequence of scoliosis or the problem is in the central nervous system systems that control balance, which suggests a potential etiological factor. Further studies on balance in this population are needed to deepen knowledge in this area. It would be important to examine the validity and reliability of clinical balance tests in relation to posturography, in order to justify their clinical application in this population. Also, examining the impact of different treatments and exercise methods on balance performance would be significant.

Literature

1. Jandrić S. Idiopathic scoliosis. Med Pregl. 2012; 65(1–2):35–40.
2. Weinstein SL, Dolan LA, Cheng JC, Danielsson A, Morcuende JA. Adolescent idiopathic scoliosis. Lancet. 2008; 371(9623):1527–37.
3. de Sèze M, Cugy E. Pathogenesis of idiopathic scoliosis: A review. Ann Phys Rehabil Med. 2012; 55(2):128–38.
4. Lau KKL, Law KKP, Kwan KYH, Cheung JPY, Cheung KMC, Wong AYL. Timely Revisit of Proprioceptive Deficits in Adolescent Idiopathic Scoliosis: A Systematic Review and Meta-Analysis. Global Spine J. 2021; 12(8):1852-61 .
5. Hawasli AH, Hullar TE, Dorward IG. Idiopathic scoliosis and the vestibular system. Eur Spine J. 2015; 24(2):227–33.
6. Asher MA, Burton DC. Adolescent idiopathic scoliosis: Natural history and long term treatment effects. Scoliosis. 2006; 1(1):2.
7. Bettany-Saltikov J, Parent E, Romano M, Villagrasa M, Negrini S. Physiotherapeutic scoliosis-specific exercises for adolescents with idiopathic scoliosis. Eur J Phys Rehabil Med. 2014; 50(1):111–21.
8. Negrini S, Donzelli S, Aulisa AG, Czaprowski D, Schreiber S, de Mauroy JC, et al. 2016 SOSORT guidelines: Orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. Scoliosis Spinal Disord. 2018; 13:3.
9. Weinstein SL, Dolan LA, Spratt KF, Peterson KK, Spoonamore MJ, Ponseti IV. Health and Function of Patients with Untreated Idiopathic Scoliosis: A 50-Year Natural History Study. JAMA. 2003; 289(5):559–67.
10. Negrini S, Grivas TB, Kotwicki T, Maruyama T, Rigo M, Weiss H. Why do we treat adolescent idiopathic scoliosis? What we want to obtain and to avoid for our patients. SOSORT 2005 Consensus paper. Scoliosis. 2006; 1:4.
11. Jandrić S. Scoliosis and Sport. Sportlogia. 2015; 11(1):1–10.
12. Sibley KM, Beauchamp MK, Van Ooteghem K, Paterson M, Wittmeier KD. Components of Standing Postural Control Evaluated in Pediatric Balance Measures: A Scoping Review. Arch Phys Med Rehabil. 2017; 98(10):2066–78.e4.
13. Verbecque E, Lobo Da Costa PH, Vereeck L, Hallemans A. Psychometric properties of functional balance tests in children: a literature review. Dev Med Child Neurol. 2015; 57(6):521–9.
14. Blenkinsop GM, Pain MTG, Hiley MJ. Balance control strategies during perturbed and unperturbed balance in standing and handstand. R Soc Open Sci. 2017; 4(7):161018.
15. Mancini M, Horak FB. The relevance of clinical balance assessment tools to differentiate balance deficits. Eur J Phys Rehabil Med. 2010; 46(2):239–48.
16. Haumont T, Gauchard GC, Lascombes P, Perrin PP. Postural instability in early-stage idiopathic scoliosis in adolescent girls. Spine (Phila Pa 1976). 2011; 36(13):E847-54.
17. Kloos A, Givens D. Exercise for Impaired Balance. In: Kisner C, Colby LA, editors. Therapeutic Exercise: Foundations and Techniques. 6th ed. Philadelphia: Davis Company; 2012. p. 262.
18. Horak FB, Wrisley DM, Frank J. The balance evaluation systems test (BESTest) to differentiate balance deficits. Phys Ther. 2009; 89(5):484–98.
19. Quijoux F, Nicolaï A, Chairi I, Bargiotas I, Ricard D, Yelnik A et al. A review of center of pressure (COP) variables to quantify standing balance in elderly people: Algorithms and open-access code. Physiol Rep. 2021; 9(22):e15067.
20. Dufvenberg M, Adeyemi F, Rajendran I, Öberg B, Abbott A. Does postural stability differ between adolescents with idiopathic scoliosis and typically developed? A systematic literature review and meta-analysis. Scoliosis Spinal Disord. 2018; 13(1):19.
21. Sahli S, Rebai H, Ghroubi S, Yahia A, Guermazi M, Elleuch MH. The effects of backpack load and carrying method on the balance of adolescent idiopathic scoliosis subjects. Spine J. 2013; 13(12):1835–42.
22. Simoneau M, Mercier P, Blouin J, Allard P, Teasdale N. Altered sensory-weighting mechanisms is observed in adolescents with idiopathic scoliosis. BMC Neurosci. 2006; 7:68.
23. Guo X, Chau WW, Hui-Chan CWY, Cheung CSK, Tsang WWN, Cheng JCY. Balance control in adolescents with idiopathic scoliosis and disturbed somatosensory function. Spine (Phila Pa 1976). 2006; 31(14):E437-40.
24. Lambert FM, Malinvaud D, Glaunès J, Bergot C, Straka H, Vidal PP. Vestibular asymmetry as the cause of idiopathic scoliosis: A possible answer from Xenopus. J Neurosci. 2009; 29(40):12477–83.
25. Cheng JCY, Guo X, Sher AHL, Chan YL, Metreweli C. Correlation

between curve severity, somatosensory evoked potentials, and magnetic resonance imaging in adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 1999; 24(16):1679–84.
26. Dąbrowska A, Olszewska-Karaban MA, Permoda-Białozorczyk AK, Szalewska DA. The Postural Control Indexes during Unipodal Support in Patients with Idiopathic Scoliosis. Biomed Res Int. 2020; 2020:7936095.
27. Allard P, Chavet P, Barbier F, Gatto L, Labelle H, Sadeghi H. Effect of body morphology on standing balance in adolescent idiopathic scoliosis. Am J Phys Med Rehabil. 2004; 83(9):689–97.
28. Şahin F, Urak Ö, Akkaya N. Evaluation of balance in young adults with idiopathic scoliosis. Turk J Phys Med Rehabil. 2019; 65(3):236–43.
29. Le Berre M, Guyot MA, Agnani O, Bourdeauducq I, Versyp MC, Donze C, et al. Clinical balance tests, proprioceptive system and adolescent idiopathic scoliosis. Eur Spine J. 2017; 26(6):1638–44.
30. Sawacha Z, Carraro E, Contessa P, Guiotto A, Masiero S, Cobelli C. Relationship between clinical and instrumental balance assessments in chronic post-stroke hemiparesis subjects. J Neuroeng Rehabil. 2013; 10(1):95.
31. Shin S-S, Woo Y. Characteristics of Static Balance in Patients With Adolescent Idiopathic Scoliosis. Phys Ther Korea. 2006; 13(4):47–55.
32. Paolucci T, Morone G, Cesare ADI, Grasso MR, Fusco A, Paolucci S, et al. Effect of Chêneau brace on postural balance in adolescent idiopathic scoliosis: A pilot study. Eur J Phys Rehabil Med. 2013; 49(5):649–57.
33. Marin L, Lovecchio N, Pedrotti L, Manzoni F, Febbi M, Albanese I, et al. Acute Effects of Self-Correction on Spine Deviation and Balance in Adolescent Girls with Idiopathic Scoliosis. Sensors. 2022; 22(5):1883.