POSTURAL ADAPTATION OF IDIOPATHIC ADOLESCENT SCOLIOSES (IAS)

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Abstract:

Idiopathic adolescent scoliosis (IAS) is a pathologic postural adaptation in 65% of cases of scolioses. The causes of this condition are determined or suggested by a series of scientific studies and clinical experience. The results of the studies imply the correlation of IAS, the pathologic movement pattern and the pathologic postural adaptation which is governed by the central nervous system's mode of function. The pattern of pathologic postural adaptation has been confirmed by different methods and procedures: a physiological analysis of the soft tissues and of the specific functioning of organs' systems, a biomechanical analysis of the muscles and joints, an analysis of mobility and the degree of motor function of body segments as well as of the whole body and also by the clinical experience gained from surgical and treatment procedures on children with IAS.

Key words: *idiopathic adolescent scoliosis, postural adaptation, IAS causes*

Introduction

Idiopathic adolescent scoliosis is enigmatic because it is very often found in clinical practice in young individuals as well as in students in everyday life, but the real cause of this condition has not been defined yet, hence the name *idiopathic*. The increase in incidence of this condition has resulted in a growing number of scientific studies which helps in discovering the missing pieces of the puzzle of the origin of IAS pathology.

According to the Committee of the Scientific Society on Scoliosis, Orthopedic and Rehabilitation Treatment (SOSORT), IAS is a lateral curvature of the spine in seemingly healthy children, the cause of which has not been discovered yet (Negrini, Negrini, & Santambrogio, 1995; Negrini, Antonini, Carabalona, & Minozzi, 2003; Weiss, 1992; Weiss, Weiss, & Peterman, 2003; Weiss, et al., 2006a).

The percentage of idiopathic adolescent scoliosis is 65-69% (Goldbloom, 1990, in Mann, 1990) compared to other types of scoliosis and occurs more often in women (7-9%) (Perennou, Marcelli, Herisson, & Simon, 1994). It affects .3-15.3% of the general population (Simoneau, Mercier, Blouin, Allard, & Teasdale, 2006) and, according to the position in the body, most often it can be defined as right thoracic and left lumbar IAS.

Clinical experience shows that it is possible to monitor the prevalence of IAS by means of the basic clinical IAS measuring criterion – the Cobb angle. Consequently, with a Cobb angle at 10°, the prevalence is 2-3%, with a Cobb angle over 20°, the prevalence is .3-.5% and when the Cobb angle exceeds 40°, the prevalence is less than .2% (Weiss, et al., 2006b).

IAS progression in clinical treatment is monitored by the Cobb angle, Bunnell rotation and functional tests. The fundamental pathological picture of IAS is based on the anatomical, biomechanical, physiological and neurological changes in the spine due to its varying form in all three axes and planes and is expressed through postural and scoliotic curvatures (Figure 1).

The scoliotic curvature increases in the course of everyday loads and under the influence of gravity on the body (Beauchamp, et al., 1993), which was confirmed by animal tests (underdeveloped goats) at the University of Utah where scoliosis was provoked in the laboratory and its progression and types of pathologic changes on the spine were identical in quadruped and humans (Braun, et al., 2003).

Progression of the pathologic condition reduces many body capacities, especially cardio-respiratory ones, due to the physiologic-biomechanical compensatory adaptation of the thorax to IAS (Figure 1). With IAS progression, respiratory capacity is compromised so that patients with the Cobb angle exceeding 50-70°, as candidates for surgery, have

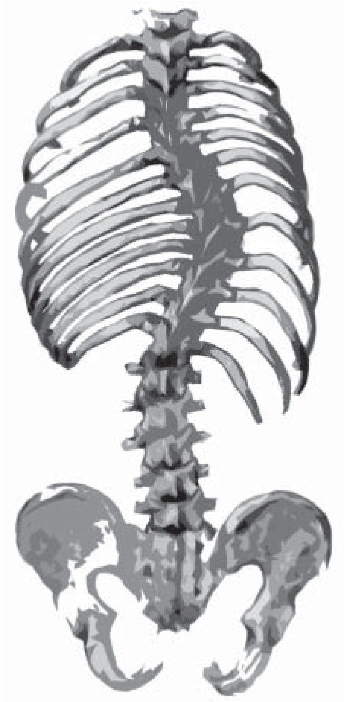

Figure 1. Pathological anatomy of scoliosis.

to undergo special physiotherapy before and after surgery in order to prepare for and improve their respiratory function (dos Santos Alves, Stirbulov, & Avanzi, 2006). Alveolar dysfunction and limited lung development were found in patients with juvenile scoliosis (Muirhead & Conner, 1985) while an irreversible status of the respiratory capacity was found in surgically treated patients with upper thoracic IAS and with the Cobb angle amounting to 70°. The IAS patients who are treated by conventional methods rarely suffer from severe reduction of vital lung capacity. Also, their death rate does not differ from the general population (Šakić, Pećina, & Pavičić, 1993).

Subsequently, IAS causes aesthetic problems and has negative effects on the ligament and skeletal systems, muscles, skin, kidneys, and blood (Worhington & Shambaugh, 1991; Lončar-Dušek, Pećina, & Prebeg, 1991). In 1993, Theologis, Jefferson, Simpson, Turner-Smith, & Fairbank quantified the cosmetic problems caused by IAS (by ISIS – Integrated Shape Imaging System, Cosmetic spinal score, Cobb angle and the assessment of postural status by neutral evaluators) and determined that in patients who had undergone surgery due to IAS there was a significant cosmetic postural problem, particularly in the status and function of the rib bones. Rinsky & Gamble (1988), Payne, et al., (1997), Climent & Sanchez (1999), Sapountzi-Krepia, et al., (2001), as well as Asher, Min Lai, Burton, & Manna (2003) found a statistically significant negative correlation between pathologic progression and mental health, sensitivity to pain and self image in patients with IAS.

Kotwicki, Kinel, Stryla, & Szulc (2007) point to the practical value of the *Bad Sobernheim Stress Questionnaire* (BSSQ) for the purpose of monitoring the stress level during the treatment of children with IAS. The BSSQ monitors and evaluates stress related to body image in the course of the entire treatment and it depends on the type of treatment.

The authors' clinical experience addresses the issue of the causal relationship between IAS factors on the basis of its increased progression upon stressful experiences (problems with school grades, family problems, etc.) because it is due to the above mentioned events and similar ones that the IAS process begins or the progression of pathologic condition continues. However, the issue of psychological categories of children diagnosed with IAS is beyond the scope of this study.

Aim of the study

The aim of this study was to review the scientific literature which directly or indirectly deals with the problem of IAS causality thus contributing to the solution of the problem – understanding the cause of pathologic postural adaptation in children with IAS.

Theories on IAS development factors

The patient asks one essential question: *What is the cause of my disease?* Meanwhile the patient's parents ask: *Is this disease hereditary?*

The genetic predisposition to IAS development was studied by Cowell, Hall, & Mc Ewen (1972), Carr, Jefferson, & Turner-Smith (1993), Lowe, et al. (2000), and Miller, Justice, & Marosy (2001). In their studies of twins, Kesling & Reinker (1997), Inoue, et al. (1998) and Burgoyne & Fairbank (2001) found that IAS develops in both children, that is, in 90% of identical and 60% of fraternal twins. Furthermore, Wise, Barnes, & Gillum (2000) revealed very interesting findings of their research. They claimed that the 6th, 10th and the 18th chromosomes were responsible for IAS.

Prevalence of the right thoracic curvature as primary in combination with the left lumbar as secondary (compensatory) curvature supports the claim about the importance of asymmetric trunk development as a putative factor in IAS development. In puberty, the risk factors in normal body growth and development are an increased growth, greater "peak height velocity" (Lončar-Dušek & Pećina, 1990; Lončar-Dušek, Pećina, & Prebeg, 1991) or an increased growth and development of the trunk measured in a sitting position (Veldhuizen, Baas, & Webb, 1986; Nicolopoulos, Burwell, & Webb, 1985) as well as asymmetry of the trunk (Nissinen, Heliovaara, Seitsamo, & Poussa (1993)). Lateralization as a direction and intensity of transmitting impulses from the central nervous system (CNS) into the periphery is completed during adolescence. Lateralization can be viewed as an inhibition or excitation for the activation of the left and right as well as the anterior and posterior side of the body (Goldberg, Dowling, & Fogarty, 1994). Also, it can be viewed as asymmetric functioning of the interdependent body segments; from the vertebral dynamic segments to the functional dependence of the pelvis, rib cage and shoulder bones. Nicolopoulos, et al., (1985) found a discrepancy in the growth and development of the skeleton in children with IAS, subsequently, the discrepancy remains causing problems with postural function. Skeletal discrepancy in IAS occurs in two types: asymmetry of the left and right side of the body and a cephalocaudal change in the trunk.

Experience of clinicians as well as of the IAS population points to certain causes of pathology such as collagen disorder as a metabolic disorder (Worhington & Shambaugh, 1991), anomalies in gingival development (Pećina, 1986; Pećina, Lulić-Dukić, & Pećina-Hrnčević, 1991) and an imbalance in the development of body segments in the period of intensive growth and development.

Due to this, individuals with scoliosis have a statistically significant greater angle of the femoral cervix on both hip bones than the individuals without scoliosis (Saji, Upadhyay, Dorth, & Leong, 1995). Tachdjian (1994) explained how asymmetric development of the left and the right side of the pelvis as well as an imbalanced ossification of the *crista iliaca* significantly contributed to IAS development (Tachdjian, 1994) by claiming that the normal function of the pelvis is a prerequisite for the normal function of the spine.

Important data are related to the course and the final stage of bone development as a sign of finished growth (maturity). The following two tests are utilized for this purpose: Tanner and Whitehouse method (TW2 method) and Risser's sign method. TW2 method determines the stage in arm and hand development (development = 1,000 points). Risser's sign determines the stage of pelvic development (finalization of *os ileum* and *os ischii* ossification at about 14 years of age in girls and 16 in boys). Research by Dhar, Dangerfield, Dorgan, & Klenerman (1993) offers an important insight which supports the evidence about nonlinear bone growth (bones of the hand and arm develop before pelvic bones) which indicates that the spine delays its growth until the pelvic bones are developed. However, Hoppenfeld, Lonner, Murthy, & Gu (2004) studied the course of growth in children with IAS and found another causal factor, the rib epiphysis growth, that is, *caput costae* development which spinal development depends on (*corpus*, *arcus vertebrae* and IVD). In this way, the beliefs about IAS progression, about which Ponseti and Friedman in the 1950s claimed to be 1° per year, whereas Perennou, et al. (1994) claimed the progression to be from .3° to 1° per year. Some authors claim that progression is related to the finalization of bone growth (Larsen, 1962; Collins 1969; Bernick 1982, in Dhar, et al., 1993).

Low mineral density in bones was found in IAS patients, with calcium metabolism being particularly imbalanced compared to healthy children of the same age (Lee, Cheng, Cheung, & Gu, 2003).

IAS progression has negative effects on muscular function so that Worhington & Shambaugh (1991) confirmed that the muscular function in children with IAS was up to 65% worse than in healthy children.

Many studies point to the correlation of the nervous system dysfunction and IAS so that Barrack, Whitecloud, Burke, Cook, & Harding (1984), Keessen, Crowe, & Hearn (1992), as well as Zabjek, Coillard, Rivard, & Prince (2008) emphasized the relationship of proprioceptive dysfunction and spinal asymmetry, claiming that there is a neurologic deficit in children with IAS compared to healthy children, whereas a proprioceptive defect in the knee joint in the form of angle reproduction ability deficit and the reproductive ability to change the position of a segment was found by Barrack, et al. (1984); Huynh, Aubic, Rajwani, Bagnall, & Villemure (2007) who compared the biomechanics of children with IAS and found a correlation of asymmetry in the central nervous system development and pathological forms of development in those children.

Greater lateralization in children with IAS suggests a correlation between this pathologic condition and a diminished function of the motor cortex (Goldberg, Dowling, Fogarty, & Moore, 1995).

Nagai, Tsuchiya, Maruyama, Takemitsu, & Nonaka (1994), Beheshti (1993) and Goldberg, et al. (1994) Lowe et al. (2000), Veldhuizen et al. (2000) claimed that all the patients with IAS required a detailed neurologic analysis.

Posture and postural adaptation of idiopathic adolescent scoliosis

Posture is a position of the body preparing for movement as well as a combination of body segments at a specific time. The position of one point (segment) affects other segments and the overall posture (Magee, 1992). A basic condition for correct posture is minimal stress, therefore, if a certain position increases stress, the postural body adaptation is incorrect (Smith, Weiss, & Lehmkuhl, 1996).

Postural adaptation develops in accordance with the development of the central nervous system (CNS), so that an evaluation of the postural adaptation is at the same time the evaluation of the central nervous system's development, particularly until 1.5 years of age in children.

Postural adaptation is the basis of motor skills development as well as the backbone of physiotherapeutic procedures enhancing the development of normal motor skills (patterns of normal movement).

Regardless of the CNS hierarchy, there is a simultaneous and parallel activity of a series of its centres providing motor skills control; therefore, a normal postural adaptation includes a number of subcortically controlled and automated activities. An illustrative example of this is maintaining an appropriate head position with regard to the body position and the extremities. The role of the cervical spine and position of the head in postural adaptation due to undisturbed proprioception by cervical vertebra facets was confirmed by a number of authors (Greenhalgh, Collins, & De Luca, 1999; Michaelson, et al., 2003). Therefore, regardless of the cause of the cervical vertebra imbalance and changes of head position (whiplash injury, cervical syndrome or IAS), it will result in inadequate postural adaptation and a problem of proprioception. Extensive pathologic changes in IAS occur exactly in the cervical spine and head position as well as in lumbar spine and pelvic position. The reason for this is the fact that the head and the pelvis are the *keys* to postural adaptation and they are used in the evaluation of postural adaptation, particularly in physiotherapy, as the main bases of transformation of children with IAS.

King (Lehneth-Schroth, 1992) made IAS classification according to anatomical sites of the spine and trunk deformity and marked the *apex* as the vertebra which is in the maximal declination from the medial body axis. In the 1980s, the classification based on anatomical biomechanics was not considered very reliable. Lehneth-Schroth (1992) contributed to a better IAS classification by determining the functional segments of the body.

The site of the curve is determined according to the peak or the apex of the curvature so that the convex side of the compensatory curve is placed opposite the primary curvature due to a postural adaptation of the body, that is, due to the basic need to maintain the body in an upright, sitting or some other balanced position. The aim of postural adaptation is to direct the gaze away from the ground and to release the arms and legs in order to establish a balance of the body and independence in certain surroundings regardless of the fact that balance in IAS patients is based on a pathological pattern (engram).

The consequence of vertebral rotation and torsion is the asymmetry of the trunk in the form of a rib hump and as changes in frontal, sagittal and horizontal plane (Figure 2). Lehnert-Schroth (1992) described scoliotic spine as a three-dimensional pathological deformity which is a combination of a rib valley on the concave side and a thoracic hump on the convex side.

The result of the multiple rib rotation is a lateral spinal shift which causes a lumbar hump under the rib valley, and a concave curve develops under the thoracic hump. According to its function, Schroth divides the spine into three functional entities (shoulder bones, thoracic and pelvic region) which develop in a wedge shape and rotate around the vertical axis of the body (Figure 3). Scoliotic torsion is formed as a result of scoliotic changes of the spine and its functional entities because the ribs and the spine follow the distortion of the functional entities (Lehnert-Schroth, 1992).

Some studies (Yekutel, Robin, & Yarom, 1981; Goldberg, et al., 1995) confirmed the change of spinal function in patients with IAS as well as the importance of a normal proprioceptive connection for achieving a normal postural adaptation. In addition, Viola & Andrassy (1993) pointed to the reduced overall physiological amplitude of spinal movement and also to increased rotation and flexion of the spine in children with IAS.

By measuring movements in the sagittal, frontal and horizontal plane in patients with IAS, it was found that an increase of the pathological

Figure 2. Characteristics of spinal and rib distortions in scoliosis.

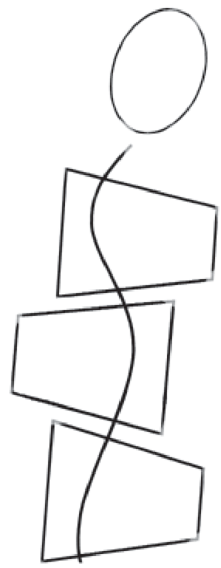

Figure 3. Pathological arrangement of body segments in IAS (posterior view).

curvature of the spine conditioned the reduction of its mobility (Poussa & Mellin, 1992; Bermejo, Jimenez, Fernandez-Palomeque, & Munuera, 1993) as well as the prevalence of dysfunctions in the system of balance measured in the sitting position (Marras & Granata, 1995).

Ruggieri & Sera (1996) analysed the perception of the body in the organization of postural adaptation during movement and found that postural adaptation is ensured by orientation points in the body segments. Adaptation is performed by a change in muscle tonus, by a change in the receptor sensibility of the joints and connective tissues as well as by adaptation of the spacioception system, which in IAS patients does not contribute to normal postural adaptation because every mentioned factor is imbalanced (within its function and particularly in connection with the accompanying segments).

The basic postural problem in IAS is proprioception, especially in specific segments of the body: in the entire spine, while an even greater problem is the pelvis. Pelvic engram in IAS seems completely distorted to a physiotherapist, which can be concluded easily at first sight upon a postural evaluation regarding the position and functional ability of the pelvis in IAS. Vertebral torsion and asymmetry of the trunk in relation to vertical axis of the body in IAS is a problem of motor deficiency and results in an aggravated control of balance in girls with IAS.

Bryan, Caggiano, & Lephart (1999), and Ghosh (2003) explained the maintaining of balance in the standing position by two strategies: ankle strategy, which ensures anterior-posterior balance relationships as well as the hip strategy ensuring rotation and other balance relationships. Simple, smaller forces are managed by ankle strategy; on the other hand, the hip strategy is responsible for greater and more complex forces. Coppieters, Knox, & Hodges (2004) emphasized a correct perception of the surroundings and the role of head and eye position in order to maintain a normal postural adaptation. Therefore, the physiotherapist was correct in concluding that the pelvis is essential in following normal postural patterns.

Proprioceptive deficiency in IAS can be confirmed either directly or indirectly by the following research.

Golie, Evans, & Bach (1992) claimed that standing on one foot is an important predictor for balance evaluation. Hoogvliet, van Duyl, Bakker, Mulder, & Stam (1997) used a stabilometric platform to analyse and determine factors for maintaining balance on one foot. It was determined that a general measure of balancing is moving the centre of gravity projection segments on a foundation; likewise, the mechanism for postural adaptation is responsible for maintaining the balance on one foot. Evaluation of postural adaptation in standing on one foot was performed in healthy subjects by a stabilometric platform using the vertical, mediolateral and horizontal components. It was concluded that postural adaptation depends on relations between lateral malleoli, foot inclination angle, body weight, the width of the foot, the segment of the foot into which the gravity centre is projected and the ability to adequately reposition the body segments' centres of gravity projections as well as the centre of gravity of the whole body. Results of the study by Filipović (2003) which applied coordination tests for children in adolescence, and by which it is possible to differentiate children with a postural adaptation problem, such as children with IAS, from healthy children, support the significance of the above mentioned factors for IAS evaluation as well as the significance of proprioception.

It was determined by biomechanical analysis of spinal ligaments that the superior costotransverse ligaments are functionally significant in maintaining of active lateral spinal balance and are also a possible factor in IAS development (Jiang, et al., 1994).

Specific function of muscles in IAS

Understanding of IAS has been based on a fundamental problem of body posture caused by "shortened muscles of one side of the back and with the overstretched muscles of the other side of the back" as said in a slogan commonly used in clinical practice. However, the given definition of IAS problem is too simple, even trivial (postural adaptation of only one segment is a complex aspiration to balance all the functions of inner subsegments), but it points to the problem of musculature which is real so that many scientists who deal with IAS tackle this problem. The relation to postural muscles is mentioned in the research by Shimode, Ryuoji, & Kozo (2003) wherein they determined that the D-PMT test (pre-motor time) of postural muscles of the lowest vertebra was positive (about 10 ms, borderline value was 5 ms) in a moment of IAS progression. This indicates the causal relation of progression. Lee, Coppitiers, & Hodges (2004) and Veldhuizen, Wever, & Webb (2000) claimed that neuromuscular changes are caused by asymmetry of the transversospinal muscles which interferes with forces in the trunk.

In a surgical procedure by EMG, Maguire, Madigan, Wallace, Leppanen, & Draper (1993) studied the muscular reflex potential (medial vastus muscle, anterior tibial muscle, gastrocnemius muscle, abductor hallucis muscle) in patients with IAS and in healthy subjects. The effects of the ipsilateral and contralateral reflex activity were found in all IAS patients whereas they were not found in patients with normal posture. The abnormal reflex process can be the cause of spinal deformity in IAS in a form of segmental non-inhibition which results in spasm in paravertebral muscles and connective tissues.

Basmajan (1981, in Schultz 1982), found the cause of IAS in hypertonus of deep rotator muscles thus demonstrating reduced muscular activity on the convex side of the scoliotic curve, recorded by EMG. Consequently, they hypothesized that the reason of muscular imbalance was a secondary reaction of the body attempting to compensate the curves of the spine.

A hypothesis that the concave side of the back was hypersensitive in muscle spindles causing IAS was made by use of computer analysis of EMG signals in 24 family members suffering from scoliosis (Hoogmartens, 1980, in Shultz, 1982). Sensitivity of muscular spindles was confirmed by vibration tests which induced bilateral responses on the muscles of the back (Basmajan, 1981, in Schultz, 1982).

Attachment of the deep muscles of the back to the vertebral canal and their activity in different movements was explained by Donisch and Basmajan (1981), in Shultz (1982), so that the transversospinal muscle has the role to adjust the activity of two vertebrae (in flexion, extension and axial rotation) whereas the multifidus muscle stabilizes the vertebrae before the beginning of movement. Multifidus is active in all directions of vertebral movement whereas the longissimus muscle is active in vertebral rotation ipsilaterally (Lee, et al., 2004). The significance of the correct functioning of the multifidus muscle for maintaining postural relations and its asymmetric function in IAS was confirmed (Kennelly & Stokes, 1993).

Three-dimensional functioning of the body

Each normal movement is three-dimensional. Human body functions with the purpose of movement/locomotion, and the source of movement is the spine, that is, the vertebral dynamic segment/basic functional unit of the spine. Therefore, if the spine does not function as a ball joint (moves in all three axes and planes), as a source of movement, it will not ensure a normal movement in other segments of the body. A three-dimensional functioning of the body or normal functioning of the body is called the functional muscular figure-eight ratio.

By means of AUSCAN system, D'Amico, Grillet, Mariotti, & Roncoletta, (1995) pointed out the importance of the three-dimensional analysis of upright stance for diagnostics of IAS patients thereby confirming the possibility of determining potential rigid segments in the kinematic chain as well as the functional importance of soft tissues in spines of patients with IAS. In this way, a prognosis of the course of IAS pathological process is possible.

Negrini, et al. (1995) and Rotelli & Santambrogio (1995) confirmed the importance of a three-dimensional analysis of deformed spine kinematics by applying the three-dimensional analysis of posture to a group of subjects with IAS and the controls as well as electric muscle stimulation to the *rectus abdominis muscle, gluteus maximus muscle and abdominal external oblique muscle*. They found that there is a strategy of points in the form of peripheral proprioception receptors for adequate postural control. There is a logical and consequential reason for the analysis of the abdominal wall in patients with IAS by the mentioned authors. Namely, the region of the anterior and posterior abdominal wall is the most critical region in patients with IAS apart from the pelvis and the shoulders. Proprioceptive control is weakest at the connection of the rib cage and the pelvis so that maximal time and effort to regain function of the mentioned connection is needed in the course of treatment. The reason for this is a tonic imbalance of soft tissues, ranging from great surface to deep, short muscles of the lumbar region.

A contribution to better and safer diagnostics (less invasive than radiographs) was given by Liu, Thometz, Lyon, & Klein (2001) who used the Quantec System, which by means of stereography and optical systems of body projection on a special screen obtains 12 variables in order to evaluate the patient's posture. Another contribution was the use of Moire topography with a cheaper and less invasive type of diagnostics for IAS patients (Pećina, Kovač, Došen, & Antičević, 1984).

Andersson (1980, in Schultz, 1982), explained the strain of the paravertebral muscles, particularly upon intervertebral disc pressure, by using EMG signal to determine increased intervertebral disc pressure upon increasing the angle of the vertebral dynamic segment. Due to asymmetric loads, the pressure varies thus increasing a myoelectric signal (it is greater in vertebral body overload during rotation than in lateroflexion). The pathological adaptation of vertebral dynamic segment is multidimensional and primarily occurs in lateroflexion (Sharma, Langrana, & Rodriguez, 1995). Continuous effects of pressure due to asymmetric loads are one of the reasons for structural changes that also occur in vertebral bodies in IAS patients by taking a conical shape.

Kovač (1988) explained a paradoxical rotation in IAS patients because the thoracic vertebrae rotate in an opposite direction from the healthy ones, towards the convexity upon spinal lateroflexion.

Marras & Granata (1995) analysed muscular resistance to load which the spine carries upon dynamic torsion of the trunk by EMG signals. The obtained results point to an identification of rotation as a risk-factor for the spine, while the spinal compression during dynamic rotation is double compared to the spinal compression during static strain.

Sharma, et al. (1995) confirmed the importance of the proper functioning of spinal ligaments, particularly the supraspinal and the interspinal ligaments in flexion, and the capsular ligament in rotation. Plaats, Veldhuizen, & Verkerke (2007) pointed to the asymmetric function of the flavum ligament and the intratransverse ligament in IAS patients. Spinal ligaments are important for separate movements as well as for their combination. Also, they are important for the prevention of excessive amplitudes of movement (Kennelly & Stokes, 1993).

Simoneau, et al., (2006) found that children with IAS had a worse function of the proprioceptors when keeping balance, as measured on the balance reaction platform, than healthy children. Olafsson, Odergren, Persson, & Saraste (2002) confirmed the correlation of body asymmetry with the diminished ability of reaction in tactile tests.

Mahaudens, Thonnard, & Detrembleur (2005) found the diminished transformation of potential energy into a kinetic one as well as prolongation of activation time of the muscles such as the gluteus maximus muscle, gluteus medius muscle, the spinal erector muscle and the quadratus lumborum muscle by analysing the walk of IAS patients.

It is necessary to explain the previously mentioned research by the following causal factors of the three-dimensional functioning of postural adaptation in patients with IAS.

The spine is a ball joint according to its function so that it cannot fulfil any kind of function without the participation of every vertebral dynamic segment. IAS changes the harmony and symmetry of their functioning but it also maintains the basic rules of function: functional muscular figure-eight ratio (three-dimensional aspect of function). The functional muscular figure-eight ratio in IAS is not as harmonious in its form (appearance) and function as in a healthy spine but it maintains a basic/minimal function as long as possible. According to Filipović (2003) children with Cobb angle of 41° are slower but accomplish tasks in coordination tests in the same way as healthy children. Therefore, until a certain stage of its progression, IAS will follow the basic rules of postural adaptation.

Compensatory mechanisms of CNS for the purpose of IAS treatment

Postural adaptation is the basis of motor function during the entire lifetime, from initial developmental processes and during all stages of life. The development of the central nervous system is followed from birth by means of motor ability, evaluating the degree of its development and function. Normal movement and normal function of the body are necessary in everyday activities as well as in specific skills. The human brain has a special plasticity, which is used in different physiotherapeutic procedures, but this very ability of plasticity is used by the brain to independently, by means of compensation, perform a number of dysfunctional motor tasks. The idiopathic adolescent scoliosis is a good example of the compensatory abilities of the brain which, due to its great progression, oppose themselves to such an extent that a minimum of normal function is lost.

Compensatory mechanisms often protect our body from greater damage which would occur without them (secondary curve in IAS is protection from damage as a result of only one curve: quick loss of balance). However, timely diagnostics of IAS prevents an excessive progression into a pathological postural adaptation; the very plasticity of the brain is used in physiotherapy and the entire process is performed in such a way that the brain learns again to establish its normal function.

For a long time, there was a general belief that movement, such as it is, is a cure for all disturbances. This rule can be applied to children with a normal postural adaptation; in such children, disturbances will disappear while playing spontaneously. However, in children with IAS the postural adaptation is pathological rather than normal due to a large number of factors previously mentioned in this paper. For this reason, sport may have a positive impact on children with IAS (Dubravčić-Šimunjak, Pećina, Bojanić, & Ciliga, 1992; Pećina, Dubravčić--Šimunjak, Bojanić, & Janković, 1993). However, although the involvement in sporting activities is beneficial to children's health it is insufficient for IAS treatment. It should be complemented with a well managed, targeted process of treatment.

The beginnings of therapy, focused on teaching the brain how to establish a normal function, date back to the 1920s when Henry O. Kendall started performing therapy at the Children's Hospital School in Baltimore using the discovery that the greatest problem in scoliosis was the imbalance of muscles throughout all three axes and planes. Due to this, the process of physiotherapy is performed by means of multidimensional movements aiming at regaining the balance of both intramuscular and extramuscular coordination of the entire musculature as well as of the soft tissues and joints (Tachdjian, 1994).

Katharina Schroth, a scoliotic patient herself, created a treatment for scoliotic posture using a three-dimensional approach which is taken by the patient and guided by the physiotherapist. The Schroth method is based on sensomotor and kinesthetic principles through proprioceptive facilitation (Lehnert-Schroth, 1992). The therapy is strictly individual and includes mental re-education of movement patterns up to automatism (Weiss, 1992). Research by Weiss (1992; 1995) and Weiss, Weiss, & Peterman, 2003; Weiss & Katz (2004) confirmed the applicability and the results of the described concept.

A basic characteristic of the Schroth method and other methods aiming to prevent the progression of pathological IAS patients is a change in postural adaptation. A condition for achieving the mentioned goal is a continuous, months-long process of the application of different forms of facilitation of the postural body segments thus transforming the pathological patterns of movement into normal ones within the central nervous system. IAS physiotherapy follows the principle of treatment established by SOSORT. It consists of the use of three-dimensional (3D) physiotherapeutic exercises aiming at the re-education of postural adaptation and following physiotherapeutic standards (Stone, Beekman, Hall, Guess, & Brooks, 1979; Weiss, Weiss, & Peterman, 2003; Negrini, et al., 2003; Morningstar, Woggon, & Lawrence, 2004; Weiss, et al., 2006; Rowe, et al., 2006).

There are a large number of possibilities used to analyse the results and experiences of researchers and therapists in the treatment of IAS, but also new methods of regaining normal posture and normal movement are used; however, this is beyond the scope of this paper.

Conclusion

Posture and postural adaptation are correlated in the development of the central nervous system and indirectly play a role in the evaluation of its function in clinical practice. The central nervous system successfully combines adaptations of body segments in space and time according to environmental conditions with the purpose of ensuring the minimal function of the body. IAS is a good example of brain adaptation to pathological proprioceptive changes.

IAS is a pathological condition which causes disorders in many regularities of spinal function and in other related segments which are in charge of postural adaptation of the body. Effects of pathological postural IAS adaptation can be seen in the locomotor system, skin and other systems of the body. Results of extensive research reveal that the causes of IAS are heterogeneous.

A number of hypotheses related to IAS factors are associated with genetics, growth spurt and development in adolescence, specific development of bones and soft tissues, speculations and confirmations of neurologic functions deficit, as well as confirmed deficit of proprioceptive pathways related to postural adaptation.

Determining the causes of IAS and its consequences for body function was carried out by means of different systems: EMG, AUSCAN and other biomechanical analytical systems as well as by the clinical experience of doctors and physical therapists who treat patients with IAS.

A large number of researchers stopped their research when they encountered the problem of proprioceptive function in IAS as a result of CNS function, which will find any possible way of its adaptation in order to ensure the functioning of the body through a pathological functional model of postural adaptation – IAS.

The very process of physical therapy uses the logic of pathological postural adaptation, only with the opposite aim, to re-educate the brain to regain normal function while reducing the effects of pathological models of postural adaptation as a form of IAS treatment.

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POSTURALNA ADAPTACIJA IDIOPATSKIH ADOLESCENTNIH SKOLIOZA (IAS)

Idiopatska adolescentna skolioza patološka je posturalna adaptacija u 65% slučajeva između ostalih skolioza. Uzroci nastanka utvrđeni su ili se pretpostavljaju kroz niz znanstvenih istraživanja i klinička iskustva. Istraživanja ukazuju na povezanost IAS s patološkim obrascem pokretanja i patološkom posturalnom adaptacijom koju uvjetuje način funkcioniranja središnjeg živčanog sustava. Obrazac patološke posturalne adaptacije potvrđen je iz više kutova; fiziološkom analizom mekih tkiva i specifičnosti funkcioniranja organskih sustava, biomehaničkom analizom muskulature i zglobnih sustava, analizom pokretljivosti i stupnja motoričke funkcije segmenata tijela i cijelog tijela te kliničkim iskustvom tijekom operativnih zahvata i terapijskih postupaka kod djece s IAS.

Ključne riječi: *idiopatska adolescentna skolioza, posturalna adaptacija, uzroci IAS*

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