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Rehabilitation in scoliosis - an overview of the most important procedures

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Abstract

Introduction: Scoliosis is defined as deformation of the spine and torso in three dimensions. Study show that scoliosis affects 68% of healthy individuals over 65 years of age with no low back pain. The aim of this article is to review the available scoliosis rehabilitation methods, including the newest physical rehabilitation trends.

Material and methods: Articles in the Google Scholar, Pub Med database have been analysed using keywords: scoliosis, deformation of the spine and torso, modern methods of rehabilitation, older people.

Results: After skeletal maturity, curves less than 30°do not progress, however most curves greater than 50°continue to progress with approximate change of 1°per year. Bracing is one of the most popular options of scoliosis treatment. Braces usage aims to slow the progression of the curve. However, complications resulting from the physical changes caused by the compression of the body and/or psychological effects due to the disturbance of the appearance while wearing the brace may occure. The Lehnert-Schroth three-plane corrective breath method principles are: a proper breathing technique where the ribs are used as levers

and the breath is directed to the unstretched parts of lungs allowing correction of the curvature of the spine, and secondly activation of non-working muscles on the side of the concave curvature. Nevertheless, surgical procedure is advised for curves greater than 45° in immature patients and greater than 50° in mature patients.

Conclusions: Scoliosis, defined as spinal and torso deformity in three planes. 80% of all cases of this postural defect are juvenile idiopathic scoliosis (AIS). However, degenerative scoliosis developed during the patient's life due to the degeneration of the discs of the spine is frequent in people over the age of 65. It often limits daily functioning and can cause severe pain that requires medical intervention. It has been proven that properly selected systematic rehabilitation may lead to significant improvement in the spinal alignment. Nevertheless, in severe cases surgical treatment may be necessary.

Keywords: scoliosis, deformation of the spine and torso, modern methods of rehabilitation, older people

Introduction

Scoliosis appears in more and more people. It is becoming a popular medical problem. It is defined as deformation of the spine and torso in three dimensions. Such pathology means that the range of spine mobility can be significantly reduced, the muscles excessively strained or stretched, and the respiratory function impaired. In addition, almost all patients experience musculoskeletal pain. The exact cause of the appearance of scoliosis is not known. Genetic factors certainly play a role. If parents struggle with idiopathic scoliosis, children will be burdened with the risk of scoliosis up to 50 times more than the rest of society. [1, 2, 3]

To determine scoliosis one should determine the angle of lateral curvature of the spine on previously performed X-ray. The Cobb method is used for this. This angle must be at least 10°. A distinctive test stating or excluding the presence of scoliosis is the Adams test. Because of the ease of carrying out the examination, you can do it yourself at home. It consists in the fact that the patient in the standing position performs the slope of the torso, remembering not to bend the knee joints. In the person with scoliosis, it is easy to see the appearance of a rib cage or lumbar spine. [4]

Scoliosis is divided into two types: functional and structural. The second one has an additional division into: idiopathic, congenital, neuromuscular and neurofibroma. The most common is juvenile idiopathic scoliosis (AIS), as it affects about 80% of patients. As the name suggests, it mainly appears in children and youth. [5]

Scoliosis is treated in two ways: surgically or conservatively. Studies have been carried out in which systematic and long-term rehabilitation can significantly reduce pain in patients. Therefore, it is the conservative treatment that is most often implemented first. It aims to compensate for muscular tension - strengthening of weakened muscles, stretching of contorted muscles, correction of general body posture, improvement of respiratory system efficiency, reduction of deformation, and if it is impossible, it inhibits further progression. [6]

Scoliosis - etiology and diagnosis

Despite many studies and analyzes, the etiology of scoliosis is not completely understood. It is believed that the variety of factors affects its occurrence. Among them you can include genetics, environmental factors, vitamin deficiency, growth hormone secretion, as well as

tissue abnormalities. The possible concepts underlying this disease will be presented below. [7, 8, 9]

Congenital scoliosis affects one in a thousand live-born children. Studies show that the haploinsufficiency of Notch signal path genes can affect this. In the mouse model, the combination of this genetic factor along with the environmental impact, i.e. short-lived gestational hypoxia, significantly increases the penetration and severity of vertebral defects. This disrupts FGF signaling and thereby germ cell somitogenesis. Somites are precursors not only to vertebrae but also to skeletal muscles, ligaments and tendons. It is worth mentioning that also unfavorable mutations in HES7 and MESP2 have been shown. They are dominant, but with little penetration. In addition, a meta-analysis of twinning studies showed that the compliance rate in monozygous twins was 73%, and in dizygous - 36%. [10]

It is believed that abnormalities in the nervous system may affect the development of scoliosis. The research revealed neuromorphological and neurophysiological disorders. The first to be mentioned are the problems with hindbrain with cervicothoracic syrinx, low-lying cerebellar tonsils with or without abnormal dynamics of the cerebrospinal fluid and the vestibular system. In disorders of neurophysiology, you can distinguish the following states: postural balance and somatosensory function equilibrium, propioceptive function and transcranial magnetic stimulation. [11]

In the etiology of scoliosis, it is worth paying attention to abnormalities of the skeletal system. Many studies have shown that people with scoliosis are higher than healthy people. It has been shown that the dependence of progression of scoliosis on growth does not depend on the speed of growth, but on the rapid enlargement of the skeleton to the size exceeding the ability to control deformation by the nervous system. [12]

Hormonal disorders are also considered as a potential causative agent. The GH / IGF axis is the basic regulator of axial growth during puberty. As mentioned earlier, growth is an important factor in the etiology of scoliosis. It is worth mentioning that the analysis of the research shows that in the early studies the level of GH did not show significant differences, while later studies found a high level of this hormone in girls, especially between the ages of 7 and 12 years. In addition, elevated levels of IGF-I were noted. The causes are also found in the incorrect regulation of estrogen, melatonin, calmodulin, leptin. [11,12]

There are also reports on the impact of environmental factors and lifestyle, i.e. nutrition, diet, calcium, vitamin D intake and physical activity. [13]

The physical examination of the patient is the most important in the diagnosis of scoliosis. The most common test is the Adam’s test, or the forward bend test. It is a screening test in which the patient bends forward with the knees and palms straight together. The examiner from the back and from the side observes the possible asymmetry of the back. Patients with scoliosis will have lateral flexion of the spine. The doctor can try to determine the degree of scoliosis with a scoliometer by measuring the angle of inclination. If the torsion angle is greater or equal to 10 degrees, an X-ray image is required. The researcher should also examine the shoulders and hips for asymmetry. With more significant scoliosis, girls sometimes notice a difference in breast size. [13, 14]

After suspecting scoliosis, a standing posterior-anterior X-ray should be obtained. In addition to testing the curve itself, attention should also be paid to vertebral bodies. At each level

should be seen two pedicles and rotation of the spain. Using an X-ray the degree of scoliosis can be accurately determined by the Cobb method. It is defined as the angle formed between a line drawn parallel to the superior endplate of one vertebra above the fracture and a line drawn parallel to the inferior endplate of the vertebra one level below the fracture. [14]

Scoliosis with a primary diagnosis must be diagnosed by a physician to identify the cause of its onset. Patients with congenital scoliosis should be examined for cardiac and renal dysfunction. Young age, rapid progression and presence of neurological symptoms speak for non-diatherical scoliosis. Most physicians, however, will encounter idiopathic scoliosis in their practice. Scoliosis in most cases is mild and rarely requires treatment. Almost 90% of cases concern the right side of the spine. If the spine is convex to the left, this may indicate the presence of additional pathology, e.g. spinal cord tumors or neuromuscular defects. Scoliosis rarely causes severe pain, so if it occurs, it should be checked e.g. for infection.
The risk of progression o scoliosis curvature, its treatment and prognosis, is based on the remaining spine growth. Simple height measurements are an effective way to monitor growth. [13, 14]

Scoliosis in the elderly

Scoliosis in old age is a serious problem in the face of which medicine is becoming helpless. One scientific study reports that scoliosis affects 68% of healthy individuals over the age of 65 with no low back pain. [15]

Aebi presents an etiological classification for adult scoliosis. There are three types of adult scoliosis. Type I caused by asymmetric degenerative changes, type II Adult Idiopathic Scoliosis (AdIS), and type III scoliosis caused by extravertebral abnormalities such as pelvic inclination or resulting from osteoporotic compression fractures. [16] The classification was published in 2005.

The next classification system was developed and published by SRS (Scoliosis Research Society) in 2006. It includes radiological images and their descriptions [17]. In the same year, another classification included a radiological image and clinical presentation (Schwab classification). [18]

In 2012, the SRS and Schwab classification were updated and merged, resulting in the SRS-Schwab classification. [19] It included relationship between spinopelvic parameters and the global sagittal balance.

Idiopathic scoliosis in adults is a result of progression or survival of adolescent scoliosis. It applies mainly to the thoracic and lumbar sections of the spine. Low back pain and stiffness are the two most common symptoms. Cases of degenerative scoliosis did not exist in adolescence, but rather developed later on in life (typically after the age of 40 or 50) due to the degeneration of the discs of the spine. Degenerative scoliosis is found only in older adults, most frequently in people over the age of 65 and is the most common form of scoliosis in adults. Scoliosis is caused by a gradual deterioration of the facet joints. [20]

Symptomatic patients are in the sixth decade of life with symptoms of spinal stenosis (90% of patients) [21]. Back pain is reported by 60-80% symptomatic patients with adult degenerative scoliosis. This pain is often intensified by exertion and often requires the patients to take a lying position to obtain relief. [22]

Historical methods of scoliosis treatment

The beginning of the history of treatment of scoliosis goes back to the time of Hippocrates (460-370 BC), which initiated treatment with longitudinal traction. [23] Traction techniques were not pleasant due to long-term sessions on the scamnum. In this way, patients were helped until the second century AD, where Galen from Pergamum modified the way Hippocrates added direct pressure in combination with traction. [24]

Ambrose Pare (1510-1590) developed the first device supporting the treatment of spinal deformities and developed a method of placing patients in a padded iron corset, which had many holes to reduce the weight of this corset. Developed by Pare orteza, he was a forerunner of modern orthopedic orthosis. [25] This method of treatment was carried out up to the nineteenth century.

Reginald Hall Sayre (1859-1929) came to the conclusion that the main cause of scoliosis is musculoskeletal imbalance, criticizing the corsets. He stated that the better way to do gymnastic exercises will be to strengthen the muscles on the convex side of the deformity. [26] The addition to the exercises proposed by Sayre was his next idea. He described the use of traction in combination with a plaster dressing to correct and maintain spinal deformities. An important event in the history of scoliosis treatment was played by Wilhelm Conrad Roentgen, who in 1895. he developed X-rays. Thanks to it, diagnosing scoliosis has become a non-invasive procedure. [27]

In 1911. Russell Hibbis performed the back spine fusion for the first time and until 1914. used this technique to treat patients with scoliosis. [23] Attempts to reduce curvature of the spine tried to surgery using bed traction and gypsum jackets. [28]

Lowett and Brewster in 1924. they came to further conclusions regarding the use of the puller (threaded screw with wing nut) for the gypsum coat. It helped to straighten the original curvature by applying transverse bending forces to the spine. [29] Then in 1931. Hibbs, Risser and Ferguson described the method of immobilizing the cast with the arthrodesis of the posterior spine. [28] In the 1950s, Risser once again modified the idea with a puller, changing it to a more contoured and lighter cast, so that patients could move freely in them. [30]

Coming back to the modern era in 1958. Walter Blount invented the Milwaukee orthosis (the name comes from the clamp that contained this orthosis), it is a cervical and orthodontic-sacral orthosis. It was the first of modern orthodontic braces. [31] After this invention, solutions that were more inconspicuous and easy to remove were sought. That's how Wilmington's buckle came about. The Wilmington plaster coat is formed in a patient placed on a Risser frame. In turn Wilmington orthoses are made to order. [32] Wanting to improve the orthosis in 1972. John Hall along with William Miller created an orthosis of prefabricated modules that were modified to order to obtain deformity correction in various patients. [33] The Boston orthodontic brace is currently used as a thoracic-sacral orthosis.

The next method used covers three generational occupations, initiated by Katharin Schroths, who began her observations on her own body. The name Schroth's method invented in the '70s is based on mirror monitoring, which allows synchronization of the correction movement and the perception of posture using visualization. Next, she introduced the current classification (single-stranded and double-lobed scoliosis) and discovered the meaning of the lumbosacral curve. She wrote this and all other information in her book, which saw the light of day in 1973. These methods were then improved by Dr. Rigo in the 90s, where the latest reports were published in 2010 and new educational approaches and correction of the sagittal profile were added. [22]

The most commonly used methods

The appropriate treatment of scoliosis is of high importance as shown by studies of the natural history of the disease. After skeletal maturity, curves less than 30°do not progress, nevertheless most curves greater than 50°continue to progress with approximate change of 1°per year. [14] This fact combined with other symptoms lowering the quality of life of the patients and often leading to severe complications stress the importance of undertaking the necessary treatment of the disease.

The treatment of scoliosis differs depending on case specifics. The choice of appropriate medication of the disease is based on the type of scoliosis, the magnitude of the curve and the patient's preference as to the shape of the back. More specific types of scoliosis, such as neuromuscular, must be treated at specialized facilities. [14]

Observation of the progression of scoliosis is crucial at an early stage. The main aim is to obtain the change of the curves under 50°at maturity. [14] Standard observation is highly recommended in the group of young patients and is often provided with school-based and physician screening.

One of the most popular options of treatment is bracing, which is mostly used in idiopathic scoliosis when there is no need of surgical procedure. The method is mostly recommended in the group of adolescents as it prevents the curve from worsening. The main aim of the usage of braces is to slow the progression of the curve and improve cosmetic appearance. [34] The mechanism of braces is based on mechanical forces correcting spinal deformity. The types ofbraces vary. The most popular are Milwaukee, Boston and Charleston bending or Osaka Medical College (OMC) braces. The usage of braces is determined by many factors and available procedures of the treatment, e.g. Charleston bending brace is worn on the inside of the bending position of the convex site only when the patient is asleep at night. [34] The complications of the treatment divide into two groups: one resulting from the physical changes caused by the compression of the body and the other based onpsychological disturbance of the appearance while wearing the brace. [34] The first group of complications comprises, among others, skin color change, tubular thorax deformity, temporomandibular joint disorder, reflex esophagitis due to the increase in the intragastric pressure and the decrement in glomerular filtration rate and total lung capacity. It should be noted that many of the aforementioned physical changes combined with other diseases of elderly patients may have an important impact on their overall clinical status. Due to the second group of complications, it is possible to observe a rapid increase from 7.6% to 82.1% in psychological problems in just one month after the start of brace treatment. [35] However, braces are still viewed as a popular method of treatment of non-operative idiopathic scoliosis.

Surgical procedure is advisable for curves greater than 45°in immature patients and greater than 50°in mature patients. [14] It is important to mention that possible surgery at an early age results in better effects of the correction of the spine curves in adulthood. The goals for surgical treatment are the prevention of progression and the improvement of spinal alignment and balance. [14] The procedure of the spine correction involves a variety of medical equipment, such as rods, hooks, screws and wires. These allow to form curves which are more similar to the physiological spine. In addition, bone grafts (autologous or artificial) can be applied in the procedure. The final result of the surgery differs depending on the type of technology used. It can be observed that good results have been found in a 20-year-follow-up period with older technology [36] whilst new technology surgery for adult scoliosis has shown improvement in radiographic and clinical outcomes as early as in a 2-year follow-up period. [37] It is important to emphasize the evolution of the operative approach and its outcomes in the past decades. The changes resulted in the cessation of anterior only surgery, increasing the use of all screw constructs, less blood loss, greater use of antifibrinolytic, shorter operative time, lower major complications rated, and greater improvement in medical

results. [38] In conclusion, new technologies of surgical treatment of scoliosis are expected to be crucial in increasing the quality of life of the patients affected by the disease.

The method of Lehnert-Schroth

The three-plane Scoliosis therapy system according to Schroth, despite its almost 100-year history, is still a widely used method in the rehabilitation of spinal curvatures. The authorship of this well-thought-out concept belongs to Katharina Schroth, who struggled with the problem of scoliosis. Based on her body observations and studies on patients, she discovered that the correction of lateral curvature and torsion of the spine can be achieved thanks to the stabilization of the pelvis and targeted breathing during exercise. Hence, the concept is also called the respiratory-orthopedic system. The three-dimensional spinal correction theory has been continued and developed by her daughter Christa Lehnert-Schroth. [40, 43, 44]

According to the recommendations of Society SOSORT (Society on Scoliosis Orthopedic and Rehabilitation Treatment), physiotherapy of patients with idiopathic scoliosis should be directed to three-dimensional deformity autocorrection, as scoliosis is considered as spinal deformity causing changes in three planes. They also drew attention to the three-plane corrective breath, which is the focus of the Schroth method. [41, 43, 44]

The Schroth system is a functional method of physiotherapy used in the case of defective spine settings. This method is based on the assumption that optimal posture correction will achieve long-term effects in the treatment of scoliosis. The most important principles also recognized as the characteristics of this method are a proper breathing and activation of non-working muscles on the side of the concave curvature. The right technique of breathing relies on using the ribs as lever arms and the breath is directed to unstretched parts of lungs which allows correction of the curvature of the spine. [40,44]

Three-dimensional deformity of the spine induces compensatory dislocations in various sections of the spine. As a result of axial rotation of the vertebrae in the thoracic spine, in the lumbar region may appear the ribbed hump and the muscular shaft. The change in the spatial body system typical of this disease leads to fix an incorrect movement pattern. The strengthening of weak muscles and proprioception exercises are indispensable for post-traumatic reeducation. [40, 41, 43, 44]

One of the main goals of rehabilitation in the treatment of idiopathic scoliosis, indicated by SOSORT members, is to improve the function of the respiratory system and prevent its dysfunctions. Lehnert-Schroth came to similar conclusions, who noticed that the use of appropriate breathing exercises delays the thoracic torsion of the spine, which is in most cases scoliosis altered. [41, 43, 44]

The starting point in begining therapy according to Schroth is to teach the patient the static starting positions and to introduce a corrective breath. An inseparable part of each exercise is the so-called rotational-angular breath which is obtained by directing the inhaled air abdominal or dorsal, to the side and towards the head. During inspiration, the diaphragm should decrease and takes action in each move. Correction of the scoliotic breathing pattern is possible in a large elongation of the torso and during relaxation of concave torso areas. [39, 43, 44]

The corrective force of therapy is properly directed three-dimensional breath. The patient should be taught to breathe consciously so that he can control the air during the inhalation in the inactive part of the torso. Intensive respiratory therapy is used, which increases the risk of hyperventilation and syncope. To avoid such situations it is necessary to increase the break time between repetitions of the exercise. Performing a corrective breath properly may be difficult for some patients. However, the starting positions used in the

Schroth method with the stabilization of the shoulder girdle and pelvis during each exercise significantly facilitate the triggering of corrective breathing. [39, 42, 43, 44]

In the next stage it is time for strengthen weak muscles and work on proprioception. Particular attention should be paid to the dorsal extensor muscle (the longissimus muscle, iliocostalis muscle). Stabilization of active correction positions can be achieved by using closed chains and triggering isometric contractions in muscles which are strengthening. Strong postural tension gives the opportunity to work more efficiently on the perimeter of the body. During exercises, asymmetrical positions are used in lying, sitting, supported knee, standing, and during gait as well. To create a closed chain, a ladder and long sticks are most often used for exercises. [43, 44]

Another important element of the Lehnert-Schroth concept is the so-called initial pelvic correction, which is performed in five stages, taking into account all surfaces and axes of the body. In the first two corrections, the body posture in the sagittal plane improves. The aim is to move the pelvis back and lift the front edge, so that the rib hump is reduced. The third correction takes place in the frontal plane, ie the pelvis is moved to the lateral displacement in the opposite direction to the protruding hip. In the fourth stage pelvic rotational movements are included, which will trigger the correction of posture in the higher sections of the torso. An important role at this stage is played by gluteal muscles. The last, fifth correction leads to a horizontal lowering of the iliac plates. Abnormal pelvic settings are the result of the scoliotic posture adopted by patients. That is why the correction of the pelvic rim is such an important element in the rehabilitation program in patients with scoliosis. [42, 44]

By implementing therapeutic tools from the Schroth method, it is possible to achieve the desired effects in patients with scoliosis. Due to the multifaceted approach and innovative solutions in relation to lateral spinal curvatures, the three-plane therapy according to Schroth has many supporters. [43, 44]

Discussion

When discussing the problem of the occurrence of scoliosis in the elderly, it is necessary to pay attention to a number of complications with which the mentioned disease is associated. This is important because they lead to a significant reduction in the quality of life and make it difficult to function. First of all, it should be remembered that scoliosis is associated with the occurrence of pain, whose causes and possible options to combat them should be the subject of research. As a model for further proceedings can be given a cross-sectional study conducted by Nakamae et al. on 120 patients aged over 65 with diagnosed degenerative lumbar scoliosis. The aim of the project was to show whether bone marrow edema can be associated with back pain in a group of respondents. After radiographs, computed tomography (CT), magnetic resonance imaging (MRI), and tender point examination in the lumbar, a much higher incidence of bone marrow edema was demonstrated in people complaining of back pain (96.9%) than non-persistent pain (37.5%). [45] This study helped to increase the knowledge of factors that may co-occur with pain in scoliosis and may contribute to the development of new effective treatments for pain in the future.

Ailments present in older people suffering from scoliosis may also take the form of spinal pain. It is related to degenerative processes, which include disc bulging, facet arthritis and ligamentum flavum hypertrophy. They all lead to the presence of symptoms of spinal stenosis, which should be kept in mind when treating patients with scoliosis. According to scientific reports, the most effective form of treatment of spinal stenosis symptoms is surgery, with 83% -96% effectiveness, but with increased percentage of complications. [46] It should be taken into account in the case of ineffective physiotherapeutic rehabilitation.

Our article presents numerous therapeutic options, the choice of which depends on a personalized treatment plan. Each of these methods has advantages and disadvantages, and supporters of individual techniques often conduct scientific discussions defending their preferred behavior and pointing to the disadvantages of other methods. An example was the presentation of a case of a 65-year-old woman with degenerative scoliosis treated in Department of Orthopaedics, University of California, San Diego (USA), who had previously undergone non-operative treatment attempts without major results. While discussing the methods of further management, there was a discussion about whether surgery should be introduced. [47] Taking into account this type of controversy, it is important to be aware of the fact that patients should be treated in a personalized way, considering whether the introduction of a specific treatment technique is associated with more benefits than possible losses. The aforementioned surgical treatment of scoliosis has been studied by Smith et al., where 453 patients suffering from adult scoliosis were examined. The study tried to show whether the benefits of surgery in the elderly age are over potential complications. As stated during the statistical elaboration, the conduct of surgical treatment is beneficial for people suffering from adult scoliosis, even at an advanced age [48], which should be taken into account in clinical practice.

Conclusions

Scoliosis, defined as spinal and **torso** deformity in three planes, most often affects children in adolescence. As much as 80% of all cases of this postural defect are juvenile idiopathic scoliosis (AIS). Scoliosis which affects adults especially elderly, can cause significant pain due to the pressure of nerve roots and narrowed spinal canal. Such pathology means that the range of the spine's mobility can be significantly reduced, the muscles excessively strained or stretched, and the respiratory function impaired. It has been proven that systematic rehabilitation leads to alleviation of pain symptoms. In planning a rehabilitation program, it is important to have an individual approach to the patient, taking into account the angle of curvature, and the role of corrective exercises is to slow down the progression of curvature and correct posture.

Over the centuries, many scoliosis treatments have been developed. However, with the advancement of medical knowledge and technology, many of them have not survived the test of time. Medical methods, now recognized as historical, formed a canvas and theoretical basis for subsequent therapy programs. Orthopedic corsets currently used in the treatment of scoliosis, were used already in the sixteenth century.

Conservative treatment is not able to completely correct the posture defect, but only stop the progression of the disease. In cases where the Cobb angle is more than 35 °, surgical treatment is indicated. Due to the fact that scoliosis affects an increasing part of our society, prevention is essential, including regular physical activity, correction of a faulty body posture and strengthening the entire muscular corset.

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