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Author team:

Alyabyev V.N. (3), Anashkina M.V. (9), Apilat A.A. (4), Belyanovskaya E.A. (2), Biryulin V.I. (3), Chekhmestruk R.Y. (5), Chernyshev A.S. (3), Choporov O.N. (6, 11), Gorlov A.N. (3), Gutsalenko Y.G. (1), Khara M.в. (13), Koenig E.в. (10), Kudelina D.V. (3), Larin O.M. (3), Lvovich I.Y. (6, 11), Lvovich Y.E. (7, 12), Lyamzin A.в. (13), Lytovchenko R.D. (2), Maidaniuk V.P. (8), Malyshenko K.A. (9), Malyshenko V.A. (9), Osadchuk A.V. (10), Osadchuk I.A. (10), Mykhaylov P.I. (5), Perun I.V. (5), Preobrazhenskiy A.P. (6, 7, 11, 12), Preobrazhenskiy Y.P. (7, 12), Prokopenko E.M. (2), Romanyuk O.N. (5), Romanyuk O.V. (5), Sukhyy K.M. (2), Sukhyy M.P. (2), Yeromin O.O. (2), Zybaylo S.N. (4)

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The monograph was prepared by the authors

1. *Alyabyev Vladimir Nikolaevich*, Outhwestern State University, Russia, Ph.D in technical sciences - *Chapter 3 (co-authored).*
2. *Anashkina Marina Viktorovna,* Crimean Federal University named after Vernadsky V.I. - *Chapter 9 (co-authored).*
3. *Apilat Andrey Andreevich,* Ukrainian State University of Chemical Technology, Ukraine, master - *Chapter 4 (co-authored).*
4. *Arseniuk Igor Rostislavovich*, Vinnitsa National Technical University, Ukraine, ass. professor - *Chapter 8 (co-authored).*
5. *Belyanovskaya Elena Anatolyevna,* State Higher Educational Institution "Ukrainian State University of Chemical Technology", Ukraine, Ph.D in technical sciences, ass. professor - *Chapter 2 (co-authored).*
6. *Biryulin Vladimir Ivanovich*, Southwestern State University, Russia, Ph.D in technical sciences - *Chapter 3 (co-authored).*
7. *Chekhmestruk Roman Y.,* 3D GENERATION, Ukraine, Ph.D in technical sciences - *Chapter 5 (co-authored)*
8. *Chernyshev Alexander Savelievich*, Russia, Ph.D in technical sciences, - *Chapter 3 (co-authored).*
9. *Choporov Oleg Nikolaevich,* Voronezh State Technical University, Russia, Dr.Hab. in Technical Sciences, Professor - *Chapter 6, 11 (co-authored).*
10. *Gorlov Alexey Nikolaevich,* Southwestern State University, Russia, Ph.D in technical sciences - *Chapter 3 (co-authored).*
11. *Gutsalenko Yuriy Grigorievich,* National Technical University "Kharkov Polytechnic Institute" (NTU "KhPI"), Ukraine - *Chapter 1.*
12. *Khara Maryna,* Priazov State Technical University, Ukraine, Ph.D in technical sciences, ass. professor - *Chapter 13 (co-authored).*
13. *Koenig Elena,* Max Planck Institute for the Structure and Dynamics of Matter, Ukraine, Ph.D in technical sciences, senior scientific employee - *Chapter 10 (co-authored).*
14. *Kudelina Daria Vasilievna*, Southwestern State University, Russia, Ph.D in technical sciences - *Chapter 3 (co-authored).*
15. *Larin Oleg Mikhailovich,* Southwestern State University, Russia, Ph.D in technical sciences, - *Chapter 3 (co-authored).*
16. *Lvovich Igor Yakovlevich,* Voronezh Institute of High Technologies, Russia, Dr.Hab. in Technical Sciences, Professor - *Chapter 6, 11 (co-authored).*
17. *Lvovich Yakov Evseevich,* Voronezh State Technical University, Russia, Dr.Hab. in Technical Sciences, Professor - Chapter 7, 12 (co-authored).
18. *Lyamzin Andrey,* Priazov State Technical University, Ukraine, Ph.D in technical sciences, ass. professor - *Chapter 13 (co-authored).*

19. *Lytovchenko Roman Dmytriyevich,* State Higher Educational Institution "Ukrainian State University of Chemical Technology", Ukraine, graduate student, - *Chapter 2 (co-authored).*

20. *Maidaniuk Volodymyr Pavlovych,* Vinnitsa National Technical University, Ukraine, Ph.D in technical sciences, ass. professor - *Chapter 8.*

21. *Malyshenko Konstantin Anatolievich,* Crimean Federal University named after Vernadsky V.I., Russia, PhD in Economics, ass. professor - *Chapter 9 (co-authored).*

22. *Malyshenko Vadim Anatolievich,* Crimean Federal University named after Vernadsky V.I., Russia, PhD in Economics, ass. professor - *Chapter 9 (co-authored).*

23. *Mykhaylov Pavlo I.,* 3D GENERATION, Ukraine - *Chapter 5 (co-authored).*

24. *Osadchuk Alexander Vladimirovich,* Vinnitsa National Technical University, Ukraine, Dr.Hab. in Technical Sciences, Professor - *Chapter 10 (co-authored).*

25. *Osadchuk Iaroslav Alexandrovich,* Vinnitsa National Technical University, Ukraine, Ph.D in technical sciences, ass. professor - *Chapter 10 (co-authored).*

26. *Perun I. Viktorovich,* 3D GENERATION, Ukraine - *Chapter 5 (co-authored).*

27. *Preobrazhenskiy Andrey Petrovich,* Voronezh Institute of High Technologies, Russia, Dr.Hab. in Technical Sciences, ass. professor – *Chapter 6, 7, 11, 12 (co-authored)*

28. *Preobrazhenskiy Yuriy Petrovich,* Voronezh Institute of High Technologies, Russia, Ph.D in technical sciences, ass. professor - *Chapter 7, 12 (co-authored).*

29. *Prokopenko Elena Mikhailovna,* National Metallurgical Academy of Ukraine, Ukraine, Ph.D in technical sciences, ass. professor - *Chapter 2 (co-authored)*

30. *Romanyuk Olexandr N.,* Vinnytsia National Technical University, Ukraine, Dr.Hab. in Technical Sciences, Professor - *Chapter 5 (co-authored).*

31. *Romanyuk Oksana V.,* Vinnytsia National Technical University, Ukraine, Ph.D in technical sciences, ass. professor - *Chapter 5 (co-authored)*

32. *Shadi M S Hilles*, Istanbul Okan University, Turkey, Computer Science, ass. professor - *Chapter 8 (co-authored).*

33. *Sukhyy Kostyantyn Mikhaylovich,* State Higher Educational Institution "Ukrainian State University of Chemical Technology", Ukraine, Dr.Hab. in Technical Sciences, Professor - *Chapter 2 (co-authored).*

34. *Sukhyy Mikhaylo Porfyryevich,* State Higher Educational Institution "Ukrainian State University of Chemical Technology", Ukraine, Ph.D in technical sciences, Professor - *Chapter 2 (co-authored).*

35. *Yeromin Oleksandr Olegovych,* National Metallurgical Academy of Ukraine, Ukraine, Dr.Hab. in Technical Sciences, Professor - *Chapter 2 (co-authored).*

36. *Zybaylo Sergey Nikolaevich,* Ukrainian State University of Chemical Technology, Ukraine, Ph.D in technical sciences, senior scientific employee - *Chapter 4 (co-authored).*

Content

CHAPTER 13. THE INFLUENCE OF TRAFFIC FLOWS ON THE LEVEL ENVIRONMENTAL SAFETY OF LIFE UNIT OF SOCIETY

CHAPTER 5.
THE USE OF THREE-DIMENSIONAL MODELING FOR HUMAN SPINE DIAGNOSTICS AND TREATMENT

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Introduction

Today three-dimensional modeling [1-8] is widely used in different branches of medicine because it helps to increase the reliability of diagnostics and conducting rehabilitation measures.

During diagnostics, three-dimensional model of the human body [1, 5, 7] helps to obtain objective parameters reflecting the condition of the osteomuscular system. Such detailed information cannot yet be given by any other currently existing technology for detecting problems of the locomotor apparatus.

Obtained data is processed by the computer and a voluminous model is displayed on the screen together with all the qualitative and quantitative indicators of the human body in calm state and in movement as well as a pictorial diagram of the smallest deviations from the norm and all the weak points of the locomotor apparatus.

It gives an opportunity of using three-dimensional modeling effectively in medicine for diagnostics, treatment and rehabilitation.

5.1. Analysis of the task status

The problem of diagnostics of the back is very important today.

According to medical statistics, 40-80% of people feel pain in the back in the lower portion of the spine [8]. In 10-20% of patients of employable age, acute pain in the spine becomes chronic. This category of patients often has an unfavourable prognosis for complete recovery so that the expenses of health care system for the treatment of persons of employable age suffering from chronic back pain in the spine region make up almost 80% of all the funds directed to the treatment of this symptom.

Postural disorders in people are becoming an ever more frequent phenomenon with each year. Thus, according to statistical data [8], this pathology in some form or other is found in 28% of children aged between 7 and 9 years, in 36% of children aged 10-14 years and in more than 41% of children aged 15-17 years! On the whole, up to 80% of the world population suffers from various postural disorders.

Backward curvature of the spine is called kyphosis. This physiological curvature is observed only in the thoracic portion of the vertebral column and is considered normal if the angle formed is no greater than 45 degrees. However, the thoracic portion, in particular, is more prone to pathological changes than any other portion of the spine. According to statistics of the World Health Organization, more than 70% of pathological kyphosis come from the thoracic portion, almost 20% are found in the sacrococcygeal region and only 10% come from the curvature of the cervical spine.

Backward curvature of the spine is called kyphosis. This physiological curvature is observed only in the thoracic part of the vertebral column and is considered normal if the angle formed is no greater than 45 degrees. Long-term clinical course of kyphosis leads to the appearance of a wedge-shaped vertebral deformity as well as to

the destruction of intervertebral cartilages. On the part of the muscular system, there is a sprain of back muscles as well as a functional disorder of muscles forming the anterior abdominal wall. Changes in the anatomical structure of the thoracic cavity lead to decreased rib mobility, disorders of intercostal muscle activity, impairment of respiratory function of the lungs.

Lordosis (fig. 1) is a saddleback-like spinal curvature in the sagittal plane; this disease complicates normal function of the heart, lungs and gastrointestinal tract. Patients suffering from lordosis experience metabolic disorders and deterioration of general health condition as well as rapid fatigability.

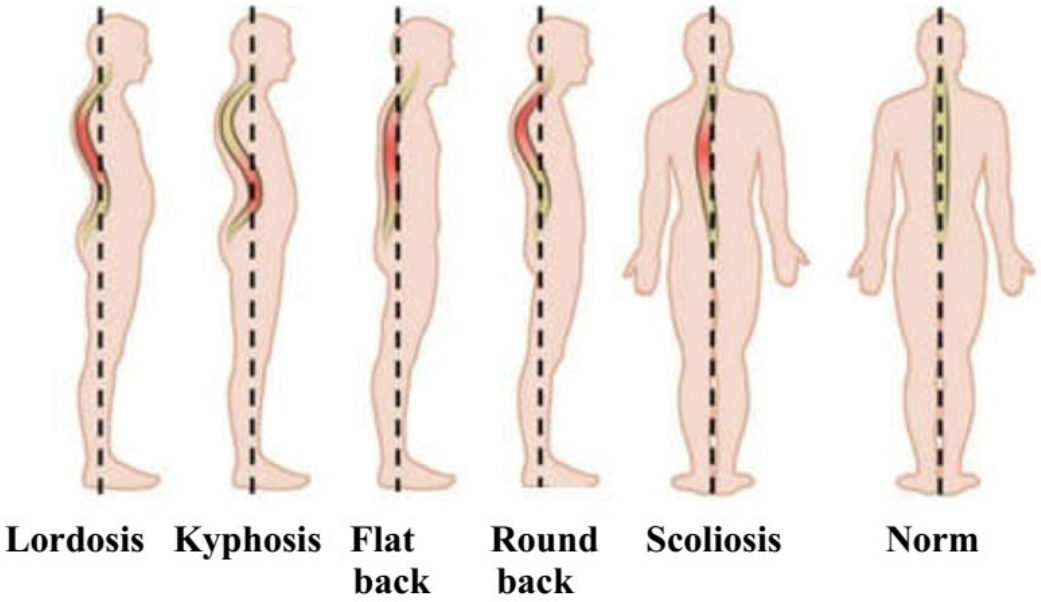

Fig. 1. Types of spinal deformities

Scoliosis (fig. 1) is a disease of the locomotor apparatus characterized by a curve of the spine in the frontal plane with a rotation (torsion) of vertebrae around their vertical axis. Formation process of a scoliosis deformity is a result of the interaction between the factors which disturb the vertical position of the spine and the adaptive responses directed towards maintaining the vertical position. Approximately in 80% of all cases the reason for appearance of curvatures is unknown.

Along with an increase in the curvature, there is an increased tendency for deterioration of problems of general health condition. Severe scoliosis can lead to deformity of torso and its shortening and can result in the decrease of the volume of the thoracic and abdominal cavities.

To determine the degree of scoliosis, doctors/diagnosticians measure the angle of the curve (fig. 2):

1. First-degree scoliosis is a curvature of up to 10 degrees.
2. Second-degree scoliosis is a curvature from 10 to 25 degrees.
3. Third-degree scoliosis is a spinal curvature of 26-50 degrees.
4. Fourth-degree scoliosis is a spinal curvature of more than 50 degrees.

Medical professionals define a range of possible reasons for a spinal curvature, and namely:

• genetic predisposition;

• congenital scoliosis in children, congenital vertebral anomalies;
• different speed of healing in one side of the body;
• low density of bone tissue;
• high pressure on the spine and spinal injuries;
• concomitant diseases (osteoporosis, osteoarthritis, disc herniation);
• metabolic disorders;
• functional disorders of the central nervous system;
• muscle disorders.

Proper posture means, first of all, a balanced body position when the load on the spine is distributed evenly. Proper posture is based not only on the spine, but also on the muscles adjacent to the spine. These muscles keep the vertebral column in proper position.

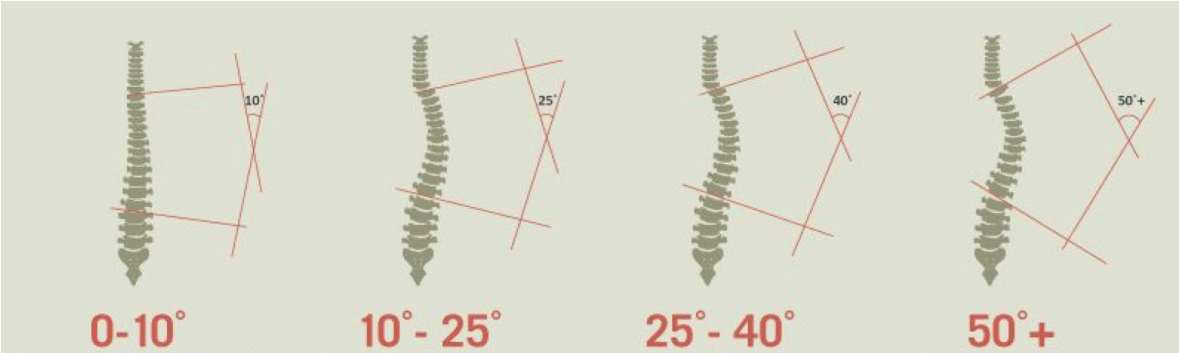

Fig. 2. Angles of spinal curvature

Main signs of proper posture:
• Straight position of the head and spine;
• Symmetrical shoulder girdles and shoulder blades;
• Practically horizontal line of the clavicles;
• Symmetrical position of the buttocks;
• Spinous processes of the spine (protuberances) forming a vertical line;
• Equal leg length;
• Proper foot position (when you put your feet together, their inner surfaces are touching from the heels up to the tips of the toes).

Curvature of the spine is considered to be harmless.

Firstly, poor posture disturbs the even, natural line of bones of the skeleton which causes chronic muscle tension.

Secondly, curvature of the back leads to reduced lung volume (for 30% or even more). And the brain is the first to suffer from reduced oxygen volume: intellectual abilities and response speed are decreased, sleepiness and depression are increased as a result of oxygen deprivation.

And thirdly, poor posture disturbs the digestive process.

Doctors use a range of devices to examine the back. The most common one is a scoliometer (fig. 3), i.e. an instrument that measures the parameters of trunk asymmetry developing in case of scoliosis.

By its design, a scoliometer is a level with an arched cutout with degrees marked upon it. The level is put against the spine of the patient who is leaning forward. A ball rolling in the arched cutout indicates the angle of inclination of the surface of the

back in relation to the horizontal line. It is possible to conduct measurements of different regions of the back determining vertebral rotation which is one of the signs of scoliosis.

Fig. 3. Scoliometer **Fig. 4. Measurement of vertebral arches**

There are also other mechanical devices (fig. 4). Their drawbacks include poor measurement accuracy, extended waiting period for results, contact measurement method and complexity of fixing the multiplicity of results.

There is a strong relationship between the condition of the spine and internal organs (fig. 5). The majority of organs of the human body are controlled by spinal cord through spinal nerves. Bad posture, excessive load that lead to the displacement of vertebrae, destruction or compression of intervertebral discs also lead to nerve compression. Connection of organs to the central nervous system is disturbed and signals coming from them are distorted. As a result, the brain receives incorrect information.

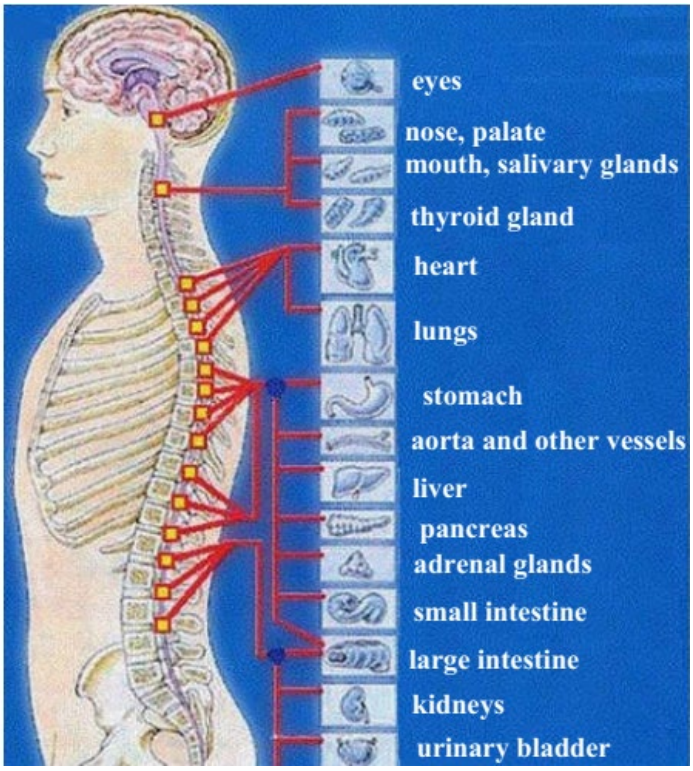

Fig. 5 Interrelationship between the spine and internal organs

Depending on the location of problematic vertebrae, certain organs suffer, for example, the nerves that come out of each vertebra and go to particular organs. There is a mutual relationship between the spine and internal organs. In some cases, it causes diseases of internal organs and in other cases disturbances of the function of organs are reflected on the condition of different regions of the vertebral column.

The provided data confirm the expediency of development and implementation of the new, effective methods for examination of the human spine.

5.2. Computer diagnostics of the spine condition

3D GENERATION LLC (https://www.3dgeneration.com) and its subsidiary 3D GENERATION UA are professionally engaged in the development and manufacture of high-resolution panoramic scanners which can be used effectively in medical practice. Fig. 4 represents one of them which includes 112 Logitech Rally cameras (960-001227) with each of them having a resolution of 8 megapixels. Three-dimensional scanning ensures high-accuracy colour imaging. Complex technologies and artificial intelligence are used to obtain photorealistic quality of 3D models.

Fig. 6. Panoramic scanners made by 3D GENERATION LLC

After obtaining a three-dimensional model (fig. 7), a person has an opportunity to examine the back in detail contrary to the regular photography which provides limited opportunities.

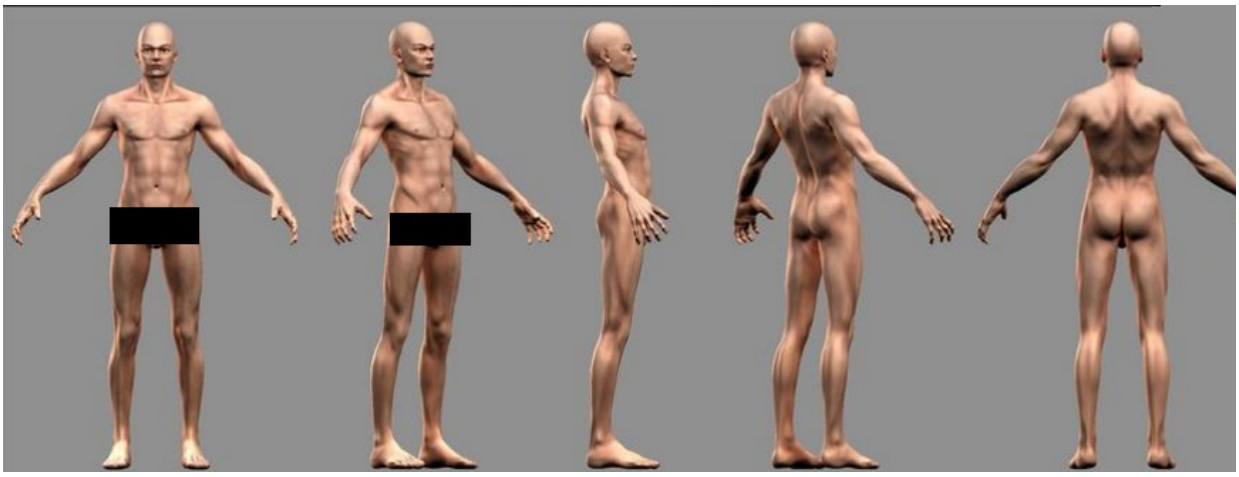

Fig. 7. Three-dimensional model of the human body

Methods of biophotogrammetry which are non-invasive methods of examination help to build a digital model of the human body surface with high precision and to visualize graphically its three-dimensional model.

Availability of three-dimensional model of the human body gives an opportunity to study intersections in the frontal, sagittal and horizontal planes which is very important for medical diagnostics.

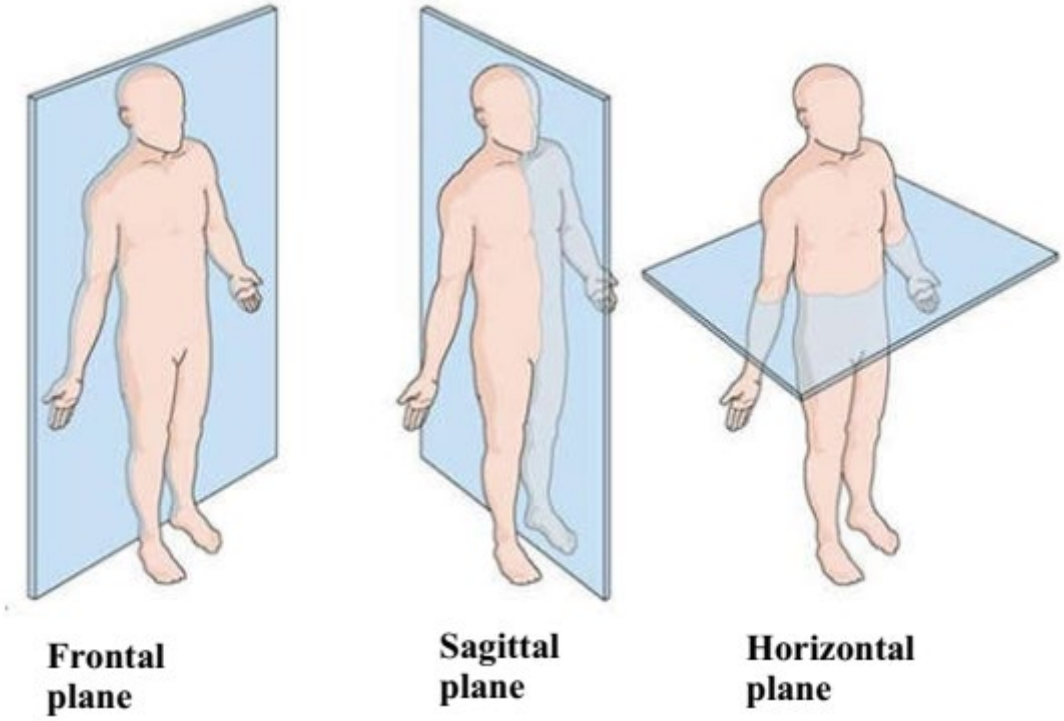

Fig. 8. Types of planes

It is possible to move the planes for the purpose of examination and accordingly receive different intersections in order to obtain a more precise diagnosis.

In the sagittal plane curvatures are regarded as the norm and straightening of curvatures is regarded as a pathology. On the contrary, in the frontal plane straight spine is normal and curvatures are regarded as a pathology (scoliosis).

After obtaining a three-dimensional model of the back, it is possible to evaluate its conformity with the standard of a healthy human being and a number of computerized studies are conducted for this purpose.

In other technologies, a patient cannot always see all his problems as it is quite hard and often impossible to evaluate yourself from the side. In the best-case scenario, an orthopaedist puts a patient before a mirror and shows him an existing pathology. That is, the patient's motivation is reduced to a minimum. Three-dimensional technology eliminates this serious drawback.

Availability of a 3D model of the back allows to compare surface patterns of the left and right regions of the back and to form an image of the surface which reflects a difference between them (fig. 9). This surface is of a high diagnostic importance. It can be used to make a spinal brace.

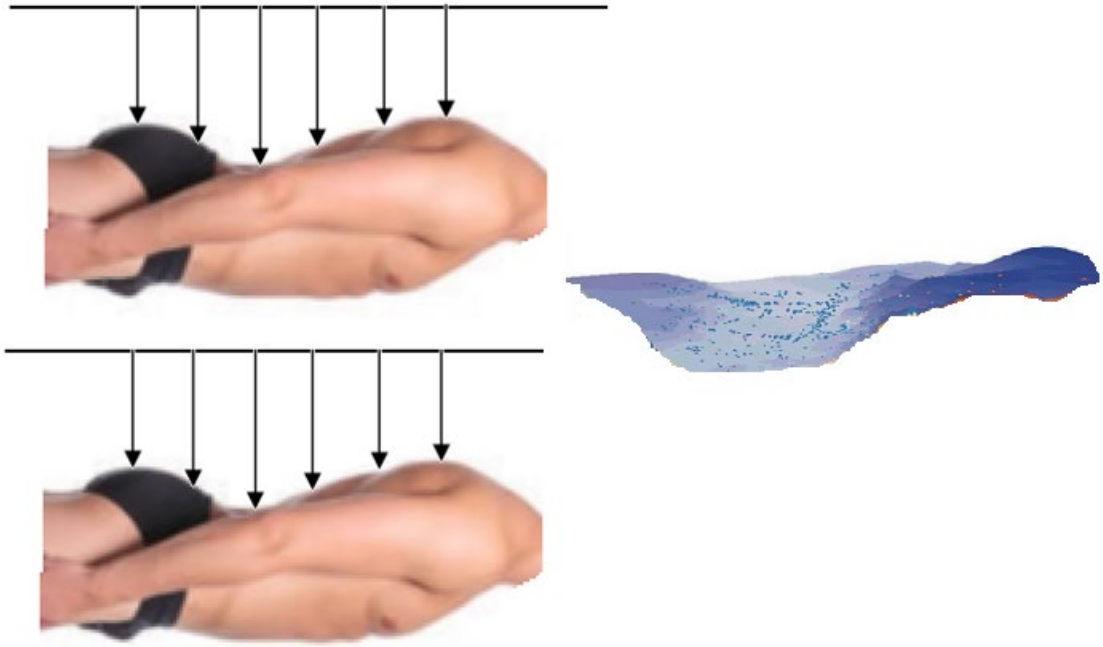

Fig. 9. Comparison of symmetrical regions of the back

Three-dimensional modeling allows for the fixity of scoliosis. For this purpose, two three-dimensions models of the back are formed over a single time interval. One model of the spine is formed with the patient standing and the other is formed in a supine position (in this case, glass surface is required). After this, the angle of spinal curvature is measured for both cases. In case of equal angles of curvature, scoliosis is considered to be fixed or stable. If in the supine position, i.e. in the unloaded state, the angle of curvature is smaller, then we are dealing with unstable or unfixed scoliosis.

Based on different locations of curvatures, the following types of scoliosis can be determined by using 3D models:

thoracic scoliosis, i.e. a curvature positioned only in the thoracic part of the spine;

lumbar scoliosis, i.e. a curvature positioned only in the lumber part of the spine;

thoracolumbar scoliosis, i.e. a curvature positioned only at the thoracolumbar junction;

combined scoliosis, i.e. a double S-shaped curve.

Three-dimensional model allows to measure the distance between the levels of scapular position (fig. 10). Difference of up to 1 cm is permissible and does not have a diagnostic meaning. Assessment of scapular position symmetry is important for diagnostics.

Fig. 10. Examination of the back

Availability of the three-dimensional model gives an opportunity to analyse surface geometry of symmetrical regions of the back (fig. 10). For this purpose, a pixel-by-pixel comparison of three-dimensional surfaces is performed. A doctor has an opportunity to perform a measurement between any given points and to determine the areas and volumes of anatomical structures.

An important peculiarity of three-dimensional modeling is a relatively easy procedure for diagnostics of lower extremity shortening.

Within the norm, in a healthy human there may be a discrepancy of up to 0,5 cm in the length of lower extremities. It can occur in 40-50% per 1,000 persons. The first sign of a gait disorder (limp) begins to manifest itself in case of a unilateral leg shortening for more than 2 centimetres. In case of 3 or more centimetres, the limp becomes more noticeable on one side.

Persons with marked leg length discrepancy and limp get tired quicker than other people because biomechanics of both legs is disturbed and a person spends more energy.

During examination, there can be a difference in the level of position of anatomical reference points, i.e. shoulder blades, greater trochanters, popliteal spaces, anterior and posterior superior iliac bones and superior poles of the patella.

When even a single line is not parallel to other lines, then it means a functional shortening of the lower extremity and when all the lines are oblique and parallel to one another, than it means an anatomical shortening of the lower extremity.

Direct measurement of leg length is also possible as shown in fig. 11.

Head tilt and additional load on the spine can be easily determined (fig. 12) using the three-dimensional model. It has a significant importance for rehabilitation measures.

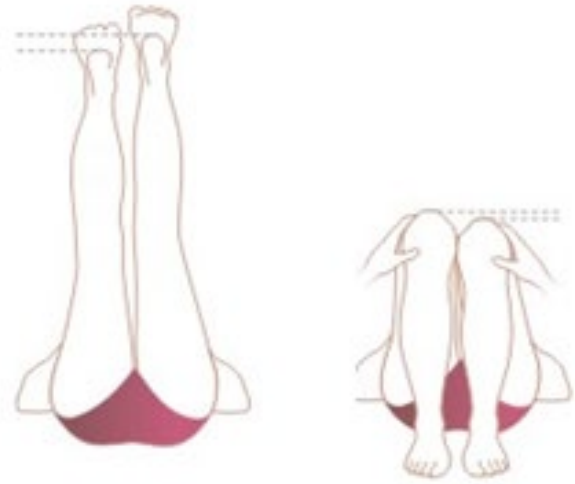

Fig. 11. Measurement of leg length

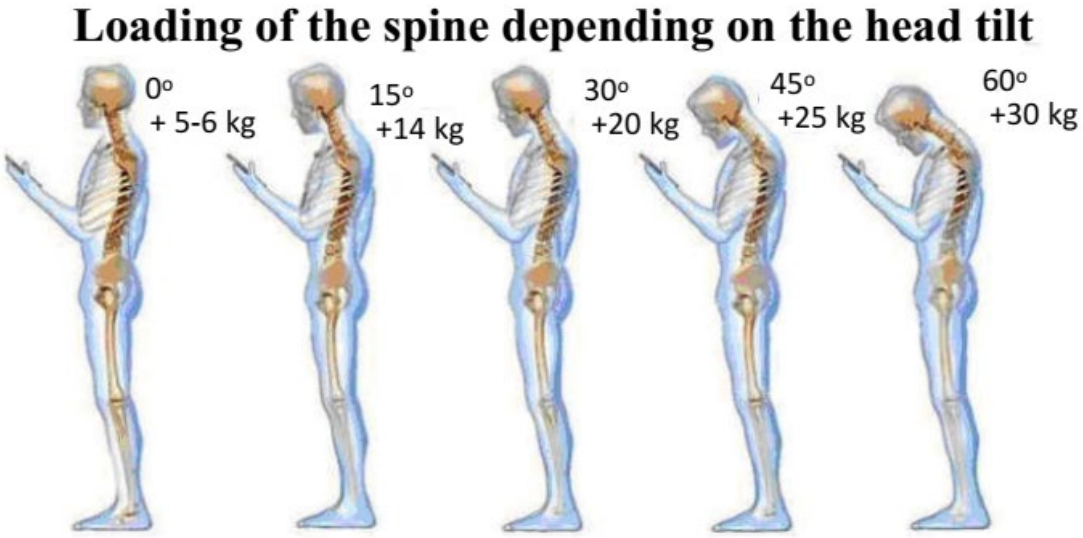

Fig. 12. Loading of the spine depending on the head tilt

Diagnostic importance of three-dimensional modeling significantly increases if certain images are projected onto the surface of the back. In the simplest case, they look like horizontal and vertical stripes.

Based on the form of overlapping stripes, a doctor can diagnose various spinal defects.

Stripes can be easily identified on the three-dimensional surface of the back because their colour differs from the colour of the skin. It allows to use computer processing.

It is possible to use various moiré patterns for different purposes depending on the diagnostics of certain disease.

Stripes can be easily identified on the three-dimensional surface of the back because their colour differs from the colour of the skin. It allows to use computer processing.

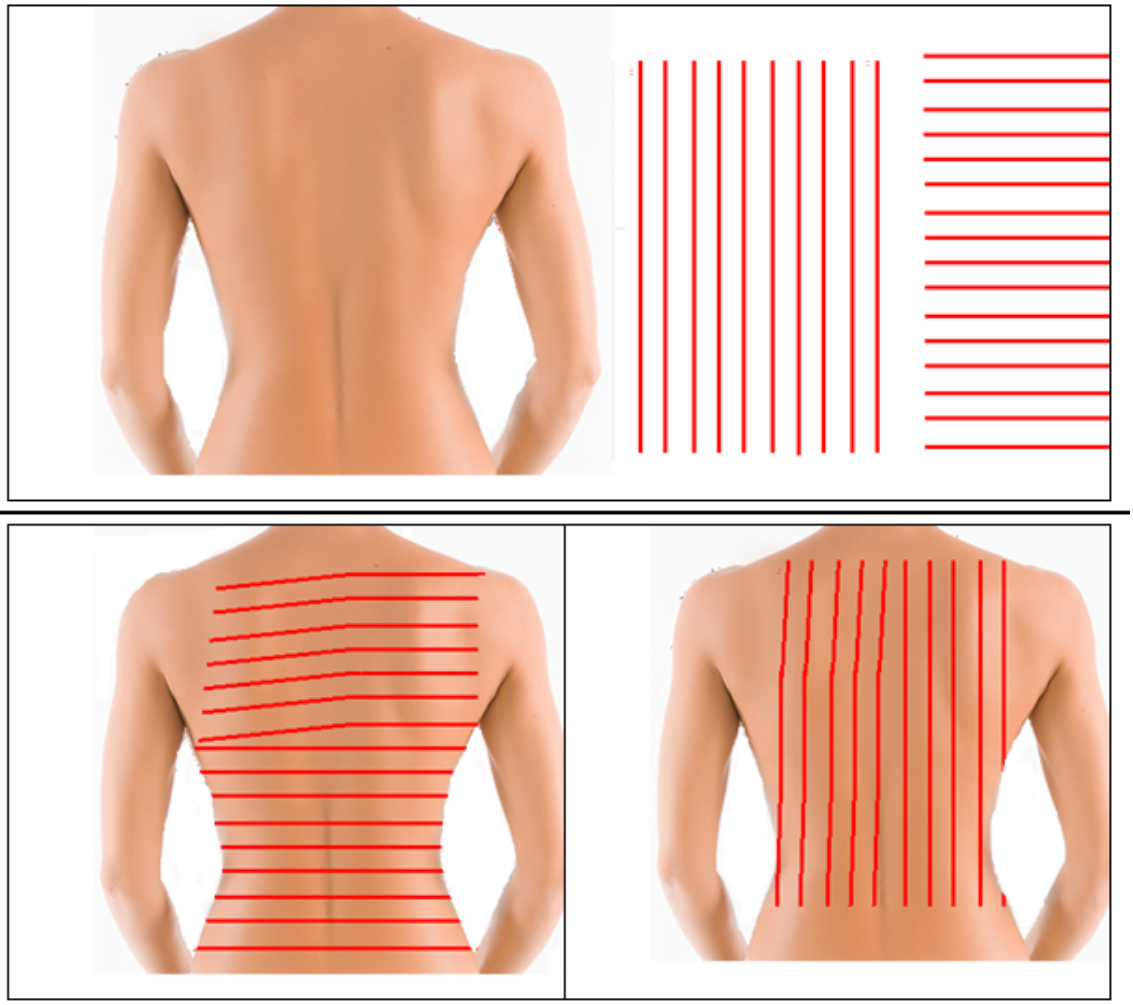

Fig. 12. Overlapping of stripe images

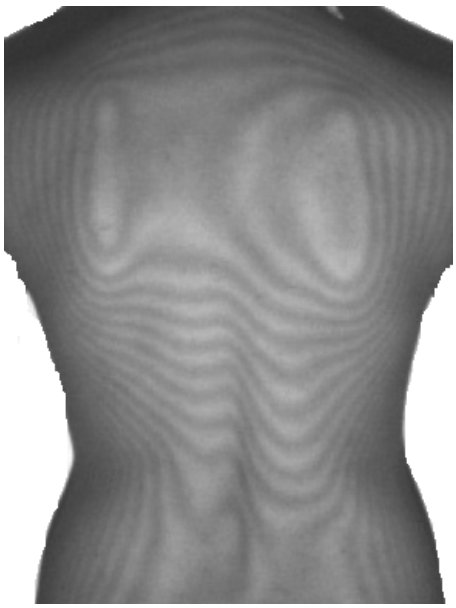

Fig. 13. Overlapping of moiré image

Based on the form of overlapping stripes, a doctor can diagnose various spinal defects (fig. 14).

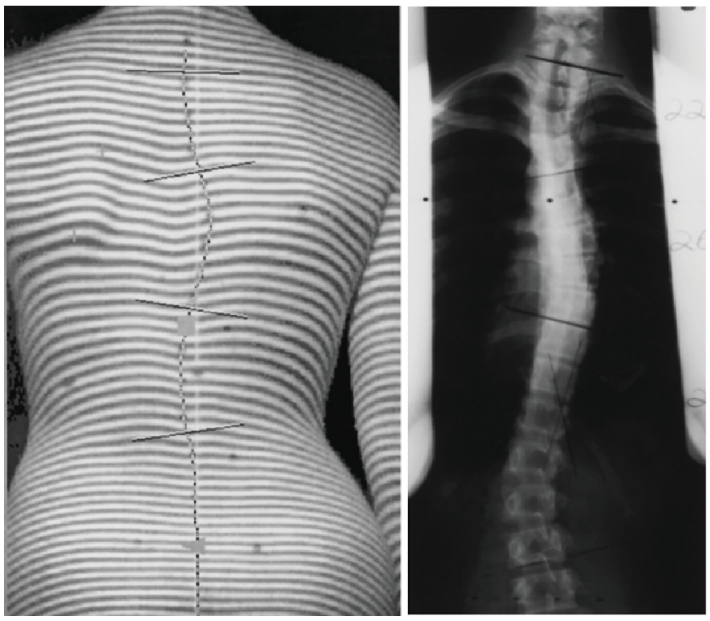

Fig. 14. Form of stripes in case of curved spine

Based on the stripes, a computer program allows to measure a range of different body parameters, for example, volume and muscle tension to the left or right of the spine (fig. 15), flexions, rotations at different levels, difference in the height of shoulders, shoulder blades and hip bones, size of scoliotic arches and physiological curvatures and many others. The obtained data are used to choose an individual therapy program.

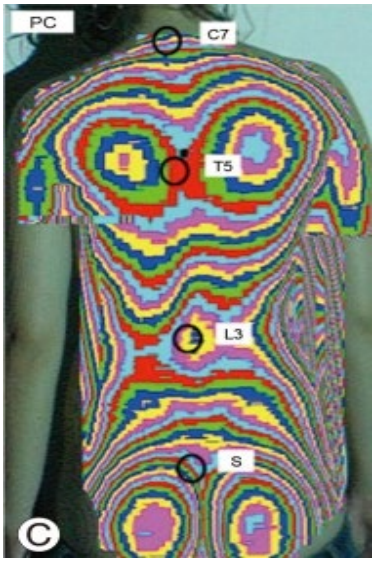

Fig. 15. Map of muscle tension

This examination gives an opportunity to evaluate in dynamics the efficiency of the performed treatment by conducting repeated examinations as well as a comparative analysis of changes in body parameters, allowing to correct the program, if necessary.

Having a three-dimensional model of the back, a map of muscle tension (fig. 15) can be formed and it can be further used for treatment and rehabilitation, and specifically for massages.

Scoliosis is a progressive spinal disease, it is expressed externally as a deformity of the body and leads to a costal humpback. In order to cure scoliosis without a surgery, it is reasonable to manufacture budget individual spinal braces based on a 3D model of the patient. Currently it is the only technology which allows to treat scoliosis and other spinal diseases without surgical intervention. Furthermore, wearing spinal braces is the only option in many cases. For example, when a surgery is impossible due to medical indications.

Orthopaedic corset is used for treating spinal diseases as well as for prophylactic purposes. It ensures vertebral fixation and spinal support in a given position as well as muscle relaxation and back straightening.

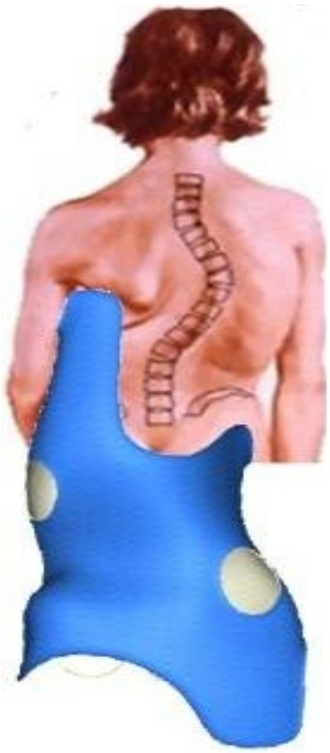

Fig. 15. Brace for curved spine

Spinal braces are most frequently used for treating scoliosis, kyphoscoliosis, kyphosis, lordosis; thoracic cage deformity; tumours and other pathologies of vertebrae; after performing surgeries.

Chêneau-type brace was developed for treating scoliosis, this brace "functions" in three planes and provides corrective influence on the scoliosis deformity, i.e. in the sagittal, frontal and horizontal planes.

Properly manufactured spinal brace of this type allows to support and stabilize the spine by preventing the progression of scoliosis in adult age.

3D method allows to precisely form the configuration of the spinal brace and, as a result, to ensure individual approach to each patient; it shortens adaptation period; it allows to eliminate problems with breathing, muscle atrophy; it does not require any serious correction; it allows to correct the delivered patient in the digital model; due to low content of plastic materials, this brace is lightweight and easy to put on.

5.3. Conclusions

The use of three-dimensional modeling for spine (back) diagnostics has the following advantages:

1. More expeditious performance of examination.
2. High reliability of diagnostics.
3. Opportunity of conducting examinations of patients in various positions.
4. Opportunity of measuring anthropometric parameters.
5. Absolute safety of this method as the body is not subjected to the influence of irradiation. This examination can be performed on pregnant women, children, persons suffering from oncology disorders or persons with cardiac stimulators. It allows to timely detect spinal disorders and diseases in certain categories of persons.
6. High demonstrativeness and realism of examination results.
7. Opportunity of properly selecting corrective means for treatment.
8. Opportunity of storing a three-dimensional model of the back for the purpose of its use within a specified time interval. The data for all results of examinations are stored in the database.
9. Opportunity of predicting the development of pathologies.
10. Expeditious development of treatment tactics.
11. Three-dimensional image may be reproduced in various planes, and namely in the horizontal, frontal and sagittal plane.
12. Opportunity of examining selected areas of the back in detail through scaling, rotation, metrological measurements.
13. Relatively low price of examination.
14. Non-contact method of examination which excludes possible errors.
15. This method allows to determine the degree of torsion and displacement which is very important for determining the treatment.
16. Opportunity of remote transfer of the data for telemedicine purposes.
17. Three-dimensional model can be scaled up or down, the object can be viewed from different angles. An important feature of the model is an opportunity to conduct metrological examinations of the patient.