fizjoterapia polska

POLISH JOURNAL OF PHYSIOTHERAPY

OFICJALNE PISMO POLSKIEGO TOWARZYSTWA FIZJOTERAPII

THE OFFICIAL JOURNAL OF THE POLISH SOCIETY OF PHYSIOTHERAPY

NR 4/2023 (23) KWARTALNIK ISSN 1642-0136

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MEDICAL INNOVATION

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nr 4/2023 (23)

Utilizing EOS method to support diagnosis and treatment implementation in physiotherapy

Wykorzystanie metody EOS do wsparcia w diagnozowaniu i wdrażaniu procesu leczenia w fizjoterapii

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Abstract

Objective. The aim of this study is to describe the EOS method in correlation with other imaging studies within the field of medical diagnostics and demonstrate its utility in the diagnosis and implementation of treatment in physiotherapy.

Materials and methods. This article utilizes available literature on medical imaging, including the EOS method. Additionally, the second part of the article illustrates the usefulness of EOS examination through a patient case study in the process of diagnosis and treatment in physiotherapy.

Conclusions. The patient case example presented in this article demonstrates the utility of EOS examination as a supportive tool in the process of diagnosis and treatment within physiotherapy. The EOS equipment, complemented by integrated software, provides measurements of individual bone lengths, joint rotations, and axes and angles within the skeletal structure of the examined patient. The 3D visualization allows for assessing the functional state of the individual with a lower radiation dose compared to X-rays and computed tomography, making it conducive to frequent utilization in analyzing changes during the treatment process.

Key words:

EOS, ITBS, medical imaging

Streszczenie

Cel pracy. Celem pracy jest opisanie metody EOS w korelacji z innymi badaniami w ramach diagnostyki obrazowej oraz wykazanie użyteczności niniejszej metody przy diagnozowaniu i wdrażaniu procesu leczenia w fizjoterapii.

Materiał i metodyka. W ramach artykułu wykorzystano dostępną literaturę przedmiotu dotyczącą diagnostyki obrazowej uwzględniającą metodę EOS. Jednocześnie w drugiej części artykułu wykazano na przykładzie pacjenta użyteczność badania EOS w procesie diagnozowania i leczenia w fizjoterapii.

Wnioski. Użyty w niniejszym artykule przykład pacjenta wykazał użyteczność badania EOS jako wspierającego w procesie diagnozowania i leczenia w ramach fizjoterapii. Sama aparatura EOS wsparta zintegrowanym oprogramowaniem ukazuje i oblicza długości poszczególnych kości, rotację w ramach stawów kończyn oraz osie i kąty w ramach struktury szkieletu badanego pacjenta. Wizualizacja 3D pozwala na zobrazowanie stanu funkcjonalnego badanej osoby przy jednoczesnym wykorzystaniu mniejszej dawki promieniowania niż rentgen i tomografia komputerowa. Sprzyja to częstszemu wykorzystaniu niniejszej metody w analizowaniu zmian w ramach procesu leczenia.

Słowa kluczowe:

EOS, ITBS, diagnostyka obrazowa

doi.org/10.56984/8ZG20A1C4

Introduction

Advancements in medical technology have led to the development of various methods of medical imaging. Among the most popular ones are X-rays, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography. These imaging methods are used at different stages of diagnosing a patient's health condition and implementing their treatment plan. This applies primarily to orthopedics, general surgery, neurology, and physiotherapy. One of the emerging diagnostic methods in recent years, providing precise diagnostic data, is EOS. It employs lower doses of X-ray radiation compared to traditional X-rays while offering 3D visualization by imaging in two planes simultaneously. The author of this article, in their practice as a physiotherapist, has been able to use this method to diagnose the health status of patients and initiate the treatment process. This article aims to compare various imaging methods and present a case study using EOS examination.

Description and comparison of various medical imaging methods

Radiographic examination, commonly referred to as "X-ray" (hereinafter: RTG), is one of the fundamental medical imaging techniques and often serves as a "first-line" examination in many cases [1]. It provides a fast and cost-effective method for imaging injuries such as fractures, dislocations, subluxations, or bone pathologies [5]. X-ray imaging is also employed for diagnosing rheumatic diseases, assessing their severity, monitoring disease progression, evaluating treatment effects, and potential complications [11]. In this technique, electromagnetic radiation (X-rays) with wavelengths ranging from 10-11 to 10-8 meters, generated by an X-ray tube, is used to obtain X-ray images. These images reveal the attenuation of X-rays by tissues, which increases with tissue density [1], making bones clearly visible on X-ray images due to their high calcium content, which strongly absorbs X-rays. Tendons, muscles, ligaments, and cartilage, as soft tissues, have a lower X-ray absorption coefficient than bones [10]. In the classical RTG examination, the image is two-dimensional, presenting a shadow of the examined object on a detector [1]. X-ray images are obtained using an X-ray unit, which includes:

- A lead wall with an X-ray tube and a set comprising an image intensifier -– television,
- A horizontal examination table and a vertical examination stand with a lamp [7]. During the examination, the X-ray tube remains stationary [1].

To capture X-ray images, the patient is positioned by medical staff in the appropriate postures to visualize the desired body part correctly. Commonly chosen positions for examination include anterior-posterior (AP) or posterior-anterior (PA) projections. Lateral and oblique projections are also used. The choice of patient positioning depends on the location of the abnormalities and the patient's clinical condition. X-ray ionizing radiation is not innocuous to the patient's body; therefore, selecting the appropriate projection is crucial [5]. To protect the patient from excessive ra-

doi.org/10.56984/8ZG20A1C4

diation, various techniques such as beam collimators, filters, anti-scatter grids, and compression devices are employed [7].

Another frequently used imaging method in the process of patient diagnosis is computed tomography (CT). It represents an extension of the traditional X-ray examination [1], also utilizing X-rays [8]. The fundamental difference between these methods lies in the type of image they produce. In a CT scan, the image can be both two-dimensional and three-dimensional, whereas X-ray imaging is one-dimensional. CT scans are highly sensitive for evaluating large joint structures [5]. Historically, it was the first diagnostic method for direct central nervous system imaging [12]. Unlike X-ray imaging, the procedure for CT scan is different. The patient is positioned on their back on a movable table and inserted into the aperture of the scanner. Inside the scanner (gantry), there is an X-ray tube that emits X-rays, and a detector system records the attenuation of X-rays after passing through the patient's body [8]. In a CT scanner, the X-ray tube rotates around the subject, capturing a series of images from various angles [1] and directions [8]. The radiation dose received during a CT scan is significantly higher than that in X-ray imaging. Therefore, CT scans are performed when there is a clear medical indication. Statistics indicate that the risk of developing cancer due to a CT scan is less than 1/2000. Depending on the patient's medical condition, CT scans can be replaced with less invasive diagnostic methods such as magnetic resonance imaging (MRI) or ultrasound (USG) [1]. CT scanning is often used as a complement to MRI, especially when precise visualization of bone structures is required. It is also used for patients who have contraindications for MRI [9].

Another important imaging method in healthcare is magnetic resonance imaging (MRI). Initially used to analyze the structure of chemical compounds, it has become one of the most important imaging diagnostic methods today. MRI relies on the absorption of electromagnetic waves by hydrogen atoms placed in a strong magnetic field [3]. This method is used to examine the entire body [5] by diagnosing anatomical regions and internal organs [3]. It is used to identify pathological changes, such as assessing the musculoskeletal system [5], and is particularly useful for diagnosing soft tissues [10] with a high water content [3]. This applies especially to structures located deeper within the body that are not visible in ultrasound imaging, such as joint structures, ligament systems, and joint cartilage. Using the appropriate sequence, MRI allows for imaging and assessment of the degree of damage to cartilaginous structures [5]. MRI is also used to diagnose pathological changes in the spinal canal of the spine [9]. Additionally, MRI is utilized to evaluate bone marrow pathologies. In specific cases of primary bone marrow tumors and metastases, MRI surpasses nuclear medicine in terms of effectiveness [10].

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The phenomenon of magnetic resonance occurs in the presence of a strong magnetic field, created by a large magnet that constitutes the main part of the MRI scanner, along with electromagnetic waves in the radiofrequency range from tens to hundreds of megahertz. Due to its size and strong magnetic force, the MRI magnet can attract metallic objects from a distance of approximately 3 meters. Therefore, all metallic objects, including the patient's clothing, are removed from the vicinity of the scanner to ensure patient safety. Patients with implanted metal objects that cannot be safely removed are contraindicated for MRI examinations. To achieve high-quality diagnostic images for the purpose of diagnosis, patients must remain still during the MRI scan [3]. Throughout over 40 years of utilizing this method, no adverse effects on patients' health have been reported [4].

The last of the mentioned commonly used imaging methods in patient diagnostics is ultrasound (USG). It is a technique that employs sound waves in the form of ultrasound to diagnose structures inside the body [2]. Ultrasound waves in ultrasonography serve a role analogous to the X-rays in radiology [6]. USG is the only imaging method that allows for real-time assessment of the static and dynamic states of musculoskeletal structures [5], including the stability of anatomical structures and potential conflicts between them [10]. USG is also used to evaluate and verify injuries involving muscle damage [5] and for guiding procedures such as punctures or injections (analgesic/anti-inflammatory) [10]. The ultrasound machine emits ultrasound waves into the body, which are then reflected back. Harmless to humans, the intensity of the ultrasound wave penetrates deep into the body through a piezoelectric transducer, which is stimulated by a transmitter to produce short-lived damped oscillations. When mechanical vibration encounters a boundary between organs, tissue discontinuities, fluid-filled cavities, calcifications, air bubbles, or foreign bodies, some of the energy is reflected, while the rest continues to penetrate deeper. The reflected energy is processed through electrical circuits and displayed as a luminance signal on the monitor [6]. The phenomenon of ultrasound wave reflection from structures with different densities within the body provides the ability to assess the shape, size, or structure of internal organs, for example [2]. However, in musculoskeletal imaging, different parts of the musculoskeletal system significantly differ in echogenicity. In ultrasound imaging, hyaline cartilage appears dark, while fibrocartilage appears bright. Tendons and ligaments, due to their hyperechoic nature, appear bright, but their fibrous structure is visible. Only muscles, having a mixed echostructure, produce a two-tone image [10].
One of the most advanced imaging devices in medical imaging is EOS, an X-ray machine based on particle detection innovation that earned Georges Charpak the Nobel Prize in Physics [14]. It features highly advanced 3D surface mapping software as an integral part [16]. This examination allows for obtaining X-ray images in two planes simultaneously by scanning the entire body in an upright position (as shown in

doi.org/10.56984/8ZG20A1C4

Figure 1), which simulates biomechanical loading [14] using very low doses of X-ray radiation [13]. EOS imaging enables the acquisition of digital and X-ray bone images, allowing for a projection of the entire body (skeleton) to be obtained [15]. Obtaining images in both anterior-posterior and lateral projections simultaneously enables three-dimensional (3D) imaging of the subject, which is a characteristic feature of EOS examination [15]. Skeletal elements in X-ray projections and in 3D models appear in real proportions at a 1:1 scale in terms of volume and size. Therefore, axes and angles, such as those of the spine or individual vertebrae or limbs, can be measured and parameterized with exceptional precision. Visualization of reconstructed 3D models from various positions using the sterEOS 3D software allows for imaging in the longitudinal axis of the subject, enabling the assessment of rotations of the lower limbs, joints, or spinal deformities in the horizontal plane [14].

Figure 1. EOS Apparatus Appearance. ***Source: Material provided by WizjaMed***

The development of EOS imaging technology has initiated significant advancements in orthopedic surgery, especially in spinal surgery [14], where scoliosis, multi-factorial deformities occurring in three planes—transverse, sagittal, and frontal— are common. Previously, scoliosis diagnosis relied on two-dimensional X-ray images (from the side or front), which did not provide information on horizontal deviations. EOS imaging has revolutionized scoliosis diagnostics by providing high-quality, realistic 3D visualization along with precise parametric analysis. A new concept based on vertebral vector calculations has been introduced, presenting simplified, visual, and comprehensible informa-

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tion facilitating the representation of EOS 2D/3D data, especially those seen from the transverse plane. The new EOS examination project and concept may lay the groundwork for a true three-dimensional scoliosis classification [16] and tibial rotation. Length measurements of limb bones and rotation data obtained from EOS examinations are equally accurate to those obtained from CT scans. Moreover, the patient's exposure to radiation is significantly lower than in CT scans [17], which is particularly crucial for children with lower limb length disparities who require repeated radiological assessments for evaluation and treatment monitoring. EOS examination enables precise repeated diagnostics of limb length and alignment while minimizing radiation exposure [18]. Thus, this modern device allows for a significant reduction in radiation doses while retaining valuable clinical information [13]. The most significant indicator for examination is the assessment and monitoring of spinal and lower limb abnormalities [8]. The continuous improvement of this technology and its application in medical practice contribute to the expanding potential use and increasing prevalence of EOS equipment in healthcare [13].

An example of a patient in whom the EOS imaging method was used in the process of diagnosis and treatment implementation

Patient Interview

A 34-year-old male presented to the physiotherapy clinic with pain in his right knee on the lateral side. These symptoms had been present for approximately two months before the patient sought treatment. During the interview, he mentioned that he had a sedentary job but remained active by running every other day (short distances, around 5 km) and going to the gym every other day alternated with running. He reported that the pain occurred during running and when climbing stairs, worsening throughout the day. The patient specified that no discomfort was experienced while walking on a flat surface or at rest. He admitted to emphasizing physical activity but rarely stretching after workouts. He had not experienced any injuries or traumas in the past two years. At the same time, he could not pinpoint the exact day when the symptoms first appeared. The patient had no coexisting medical conditions and was not undergoing any medical or pharmacological therapy. In 2020, he had undergone surgery to remove an ectodermal cyst from the right cerebellopontine angle without complications. He rated the pain on the lateral side of his thigh as a 6 on the Visual Analogue Scale.

Visual examination

Upon entering the clinic, the patient moved freely without apparent pain. During the visual examination of the patient in a standing position from behind, weight shift to the left side was observed, along with mild flat feet on both sides, with the right foot exhibiting slight valgus. The left hip bone plate was slightly higher than the right, while the shoulders and scapulae were aligned. In the lateral position, slight protraction of the head, deepening of thoracic kyphosis, and lumbar lordosis were noted.

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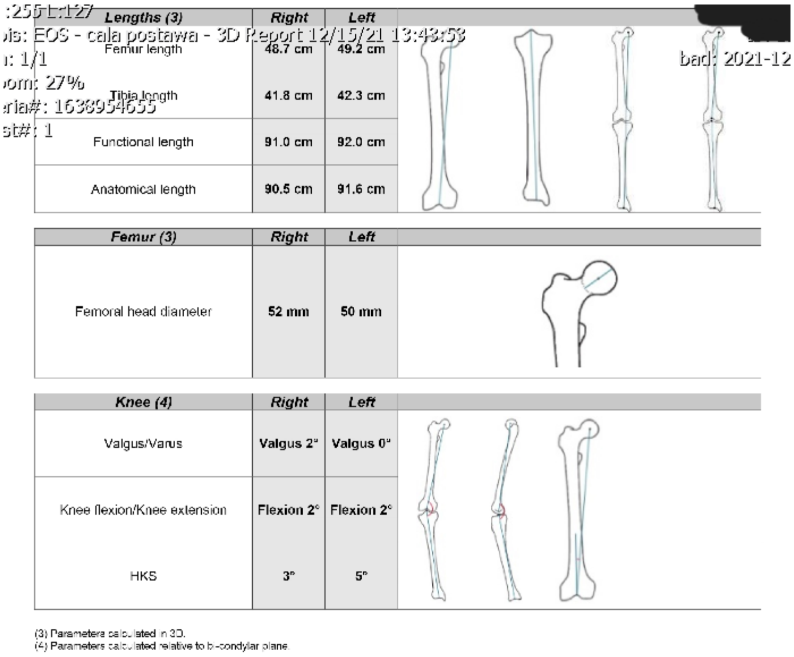

Lengths (3)	Right	Left
Femur length	48.7 cm	49.2 cm
Tibia length	41.8 cm	42.3 cm
Functional length	91.0 cm	92.0 cm
Anatomical length	90.5 cm	91.6 cm

Femur (3)	Right	Left
Femoral head diameter	52 mm	50 mm

Knee (4)	Right	Left
Valgus/Varus	Valgus 2°	Valgus 0°
Knee flexion/Knee extension	Flexion 2°	Flexion 2°
HKS	3°	5°

(3) Parameters calculated in 3D.
(4) Parameters calculated relative to bi-condylar plane.

Figure 2. Measurement of length and diagnostic imaging of lower limb bones and joints in the EOS examination of the patient
Source: Anonymized documentation from the EOS examination provided by the patient

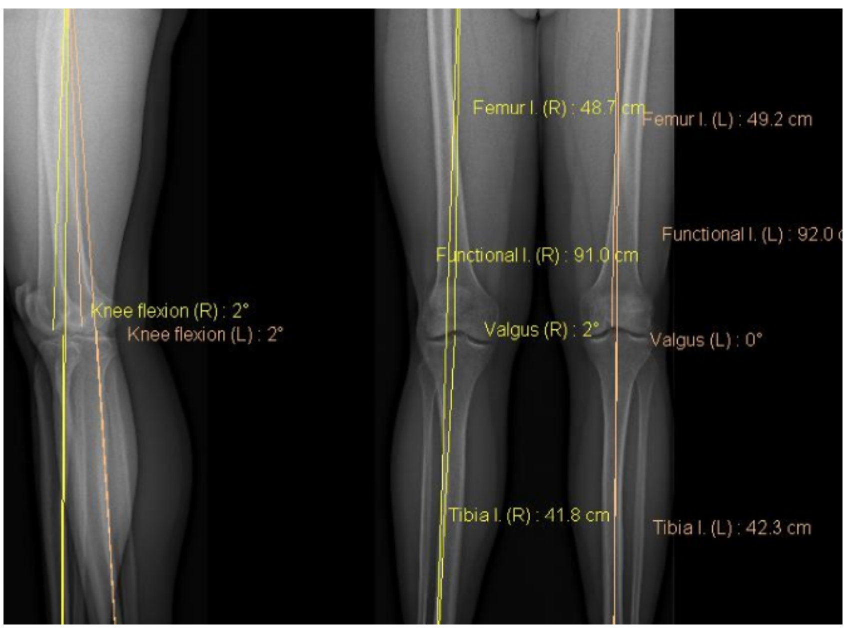

Figure 3. Imaging combined with lower limb measurements in the EOS examination of the patient
Source: Anonymized documentation from the EOS examination provided by the patient

Palpation examination

Palpation revealed excessive tension on the lateral side of the right thigh and increased tension in the back muscles. Limited mobility of soft tissues in the back and lateral sides of both lower limbs was detected. Dermatome examination did not reveal any abnormalities, as the patient felt touch equally on both sides of the back and lower limbs.

doi.org/10.56984/8ZG20A1C4

Structural and functional examination

The patient underwent the following tests: Ober's, Renne's, and Noble's tests. All three tests yielded positive results. Based on the interview and examination, including the tests, iliotibial band syndrome – runner's knee, was diagnosed. Several body dysfunctions were detected during the examination, although it was not clear which was the primary and which was the secondary cause.

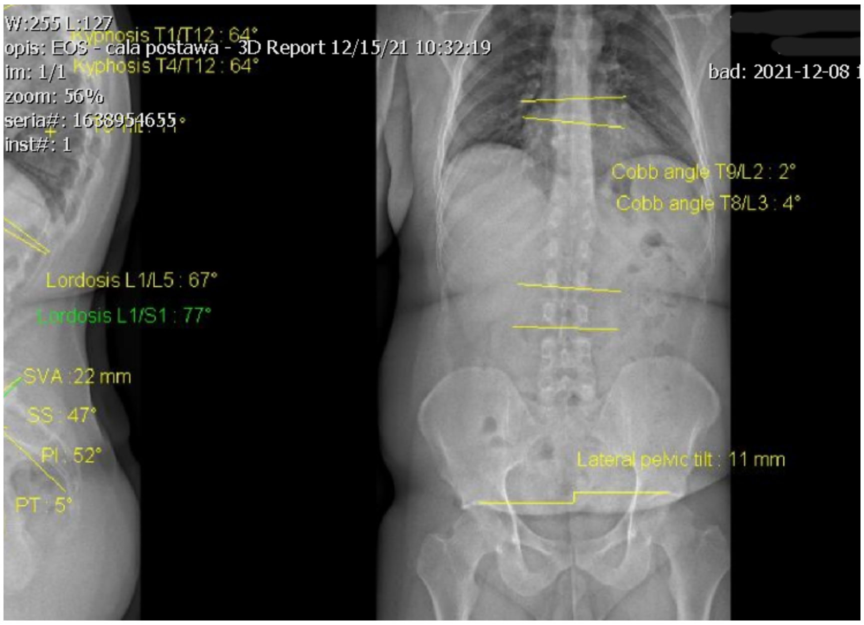

Figure 4. Imaging combined with spinal and pelvic measurements in the frontal plane in the EOS examination of the patient
Source: Anonymized documentation from the EOS examination provided by the patient

Figure 5. Imaging combined with spinal and pelvic measurements in the sagittal plane in the EOS examination of the patient
Source: Anonymized documentation from the EOS examination provided by the patient

doi.org/10.56984/8ZG20A1C4

Utilizing EOS Examination in Diagnosis and Treatment

Upon the patient's visit, an EOS imaging examination result was presented, which precisely showed the difference in the length of the lower limbs (Figures 2 and 3). The right femur measured 48.7 cm, while the left measured 49.2 cm (a 0.5 cm difference). Similarly, the tibiae also exhibited a 0.5 cm disproportion – the right measured 41.8 cm, and the left 42.3 cm. The EOS examination revealed that the patient had valgus deformity of the right knee joint at a two-degree angle and equal flexion contracture of both knee joints. Figure 4 displayed an image with the pelvic tilt in the frontal plane, showing an 11 mm difference in the height of the anterior inferior iliac spines. A slight spinal curvature was also observed in the same image. The Cobb angle in the Th_9–L_2 segment measured only 2 degrees, and in the Th_8–L_3 segment, it was only 4 degrees. Figure 5 depicted the EOS image of the patient in the sagittal plane, from which data regarding the deepening of thoracic kyphosis at Th_1–Th_{12} (64 degrees) and lumbar lordosis at L_1–L_5 (67 degrees) were obtained.

Treatment Implementation

The examinations conducted during the physiotherapy clinic visit, along with the patient's interview and EOS diagnostic data, allowed for the initiation of an appropriate therapeutic process. The EOS examination alone confirmed existing dysfunctions and deviations from accepted norms in the patient's body. Due to the lower limb pain, the focus during the visit was on soft tissue work (myofascial therapy, deep tissue massage) on the right gluteus maximus and tensor fasciae latae. The patient was advised to rest from training and perform self-therapy – stretching of the treated muscles at home. The further rehabilitation plan, after loosening tense tissues, included exercises for the right lower limb abductors and pelvic stabilizers, which, when insufficient, transferred their load to the gluteus maximus and tensor fasciae latae.

The patient visited the clinic once a week for therapy over the course of one month. The first two visits focused on loosening the contracted and overly tense structures in the right thigh and buttock. Additionally, the patient performed self-therapy – stretching exercises for the treated structures at home daily. The third visit aimed to assess the effects of two weeks of the patient's efforts, showing improvement with relaxed tissues and reduced pain during activity. A training plan for strengthening the right lower limb abductors was devised and presented to the patient. On the fourth visit, the patient demonstrated how to perform the exercises to ensure correct execution and potential corrections. The patient was advised to address the limb length difference by purchasing individually prepared insoles for the right lower limb and continue rehabilitation for postural defects in the spinal column.

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doi.org/10.56984/8ZG20A1C4

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doi.org/10.56984/8ZG20A1C4