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THE IMPORTANCE OF MONITORING WITH OPTICAL MEASUREMENTS IN ASSESSING THE EFFICIENCY OF REHABILITATION OF PATIENTS WITH DISEASES OF THE MUSCULOSKELETAL SYSTEM (literature review)

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ЗНАЧЕНИЕ МОНИТОРИНГА ОПТИЧЕСКИМИ ИЗМЕРЕНИЯМИ В ОЦЕНКЕ ЭФФЕКТИВНОСТИ РЕАБИЛИТАЦИИ БОЛЬНЫХ С ЗАБОЛЕВАНИЯМИ ОПОРНО-ДВИГАТЕЛЬНОЙ СИСТЕМЫ (обзор литературы)

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Аннотация: *В данной статье представлены результаты систематического поиска научной литературы, проведённый в базах данных PubMed, CINAHL, Embase и SCOPUS поверхностной топографии, оптическими измерениями —методов исследования без использования лучевой терапии, используемых в диагностике, мониторинге и оценке состояния больных с заболеваниями опорно-двигательной системы.*

Ключевые слова: *оптические измерения, DIERS 4D, нарушения осанки, поверхностная топография, мониторинг эффективности реабилитации*

Abstract. *This article presents the results of a systematic search of scientific literature conducted in the PubMed, CINAHL, Embase and SCOPUS databases of surface topography, optical measurements - research methods without the use of radiation therapy, used in the diagnosis, monitoring and assessment of the condition of patients with diseases of the musculoskeletal system.*

Keywords: *optical measurements, DIERS 4D, postural disorders, surface topography, monitoring the effectiveness of rehabilitation.*

Today, in modern medicine, the use of surface topography and optical measurements is relevant, which is one of the safe methods for monitoring and tracking the progression of postural deformations in patients in dynamics. Thus, our study provides an analysis of literary sources of the PubMed, CINAHL, Embase and SCOPUS databases, dedicated to the above-mentioned aspects of diagnosing many diseases.

In a study by Knott, P. (2012) and others [7], the accuracy of automatic landmark detection in the Formetric 4D system for assessing surface topography in adolescent scoliosis was investigated. The researchers found that manual adjustments to the automatically detected anatomical landmarks by the physician did not significantly change the measured scoliosis parameters. This suggests that the automatic landmark detection in the Formetric 4D system is reliable enough for clinical use and does not require significant manual adjustments. Thus, his study included 12 patients with adolescent scoliosis less than 30 degrees. The Formetric 4D system was used to take 30 repeated measurements for each patient, which allowed the system to automatically detect landmarks without physician intervention. The physician then manually adjusted the landmarks, and the same parameters were measured again. The study compared 12 parameters, including the scoliosis angle, and no statistically significant differences were found between the two sets of measurements. The authors concluded that manual adjustment of the automatically detected landmarks was not required because it did not significantly affect the measured parameters. This finding confirms the reliability of the automatic landmark detection feature of the Formetric 4D system for scoliosis assessment.

In practical recommendations H. Ch. Harzmann, (2014) describes the possibilities of integrating alternative approaches into the treatment concept along with medicine focused on clinical guidelines and an individual approach to each patient.

Later Knott, P. and co-authors recommended in their works to abandon two-dimensional studies of the spine and switch to three-dimensional and four-dimensional ones: clinical application of surface topography [8].

Bolzinger, M. in his works describes the danger of repeated X-ray irradiation in patients with adolescent idiopathic scoliosis (AIS) and speaks about the need to reduce the number of radiographs. With the help of surface topography, it is possible to evaluate the asymmetry of the trunk. The number of necessary radiographs can be reduced by 30% if X-rays are used only for patients with progressive diseases [1]

Other authors [4] have reported data from studies using DIERS 4D, which is one of the safe methods for monitoring and tracking the progression of postural deformities in patients over time. Reference values for detecting postural changes were evaluated in the study. The current study examined the reliability of spine shape parameters obtained using Formametric 4D in adults without postural disorders and established reference values to determine the moment of real change. Thirty patients were scanned over a period of 1 week. Intraclass correlation coefficients (ICC) were calculated for 40 spine shape parameters for scans when participants were stationary between scans, scans with repositioning between scans, and between days. In this author's studies, the within-day and between-day standard error of measurement (SEM), absolute relative SEM, and smallest detectable change (SDC) were reported. The ICC for stationary scans was excellent for 29 parameters, good for 10 parameters, and fair for 1 parameter. During repositioning, the ICC was excellent for 27 parameters, good for 12 parameters, and fair for 1 parameter. Between-day ICC was excellent for 26 parameters, good for 10 parameters, and fair for 4 parameters. The intra-day SEM% was greater than 10% for 6 parameters. The intra-day SDC ranged from 1.80 to 25.03 units for one scan and from 0.97 to 17.93 units for 6 scans. The inter-day SEM% was greater than 10% for 9 parameters. Interday SDC ranged from 1.44 to 28.24 units for one scan and from 1.05 to 22.2 units for 6 scans. Thirty-six of the 40

spinal shape parameters from the DIERS formetric 4D were reliably different between participants over time. Reference values were established that can be used to track patient posture change over time. The author concludes that future studies should examine the clinical significance of these 40 spinal shape parameters and determine when, at what time, clinically important postural change occurs.

Brian Degenhardt et al. also used optical measurements in their research to monitor the effectiveness of rehabilitation for postural disorders [2]. The study used the DIERS formetric 4D system (measures 40 spine shape parameters in a 6-second scan). Thanks to the system's algorithms, a set of spine shape parameter values obtained from one of 12 images acquired during scanning becomes a DIERS report value (DRV) for posture assessment. The purpose of this study was to compare the DRV with the standard mean value (SAV) calculated from all 12 images to determine which method is more suitable for assessing posture changes. In this study, one mannequin and 30 study participants were scanned over 5 days. The values of each image and the DRV values for the 40 specified spine shape parameters were exported, after which the mean DRV, mean SAV, mean DRV, and intra-scan variance were calculated. The absolute difference and percentage change between the mean DRV and the mean SAV for the manikin and humans were calculated. Inter-method reliability was calculated for humans. The within-scan variance for each parameter was tested for significant variability. For all spine shape parameters on the manikin, the absolute difference (<0.6 mm, 0.1°, or 0.1%) and percentage change (<2.90%) between the mean DRV and the mean SAV for each parameter were small. Nine parameters in human participants showed a large percentage change (>7%). The absolute difference between the mean DRV and the mean SAV for these nine parameters was small (≤0.87 mm or 0.61°). The absolute difference for all other parameters ranged from 0.02 to 6.98 mm for distance measurements, from 0.01 to 1.21° for angle measurements, and from 0.15 to 0.22% for percentage measurements. Inter-method reliability between DRV and SAV was excellent (0.94-1.00). For the manikin, the within-scan variance was small (<1.62) for all parameters. For humans, the within-scan variance ranged from 0.05 to 36.04 and was nonzero for all parameters (all $P < 0.001$). The authors concluded that the minimal variability observed in the study indicates high within-scan reliability of the DIERS formetric 4D instrument. DRV and SAV provide comparable values for spine shape parameters. Because within-scan variability is not reflected in DRV, the clinical utility of current DRV values is limited. Estimating variance using SAV will allow clinicians to better identify clinically significant changes.

Later in 2020, the same author conducted a study of the DIERS Formetric 4D spine shape parameters in adults without postural deformities [3]. The researchers show that DIERS 4D provides a safe method for monitoring and tracking the progression of postural deformities over time. The authors believe that further evaluation of reliability is needed. Reference values to indicate postural change are also needed. The current study investigated the reliability of the spine shape parameters obtained with Formetric 4D in adults without postural deformities and established reference values to determine when real change occurs. Thirty participants were scanned over a period of 1 week. Intraclass correlation coefficients (ICCs) were calculated for 40 spine shape parameters for scans when participants were stationary between scans, scans with repositioning between scans, and between days. Within-day and between-day standard error of measurement (SEM), absolute relative SEM, and smallest detectable change (SDC) were reported. The ICC for stationary scans was excellent for 29 parameters, good for 10 parameters, and fair for 1 parameter. For repositioning, the ICC was excellent for 27 parameters, good for 12 parameters, and fair for 1 parameter. Between-day ICC was excellent for 26 parameters, good for 10 parameters, and fair for 4 parameters. Within-day SEM% was greater than 10% for 6 parameters. Within-day SDC ranged from 1.80 to 25.03 units for a single scan and from 0.97 to 17.93 units for 6 scans. Between-day SEM% was greater than 10% for 9 parameters. Between-day SDC ranged from 1.44 to 28.24 units for a single scan and from 1.05 to 22.2 units for 6 scans. Thirty-six of the 40 spine shape parameters from the DIERS formetric 4D were reliably different between participants over time [3]. Reference values were established that can be used to track patient posture change over time. Future studies should examine the clinical significance of these 40 spine shape parameters and determine when clinically important posture change occurs.

Tugba Ozudogru Celik et al (2024) conducted a study using the DIERS Formetric 4D motion imaging system in patients with urinary incontinence (UI), which is a common public health problem and postural changes may be critical for women with UI [12]. The aim of this study was to evaluate the relationship between low back pain (LBP), pelvic tilt (PT), and lumbar lordosis (LB) in women with and without UI using the DIERS formetric 4D motion imaging system. And to our knowledge, no study to date has compared postural changes and LBP in women with UI using the DIERS formetric 4D motion imaging system. The study was conducted on the case-control principle. The study included 33 women with urinary incontinence and 33 without it. The severity of urogenital symptoms was assessed using the IIQ-7 (urinary incontinence assessment scale) and UDI-6 (urogenital distress assessment scale), and disability caused by low back pain (lumbosacral muscle) was assessed using the Oswestry Disability Index (ODI). Posture and movement, lower lip angle (LL), thoracic kyphosis and proximal spine (PT) assessment were assessed using the DIERS Formetric 4D motion imaging system. According to the results of this study, the LL angle and the degree of pelvic torsion were higher in the urinary incontinence group than in the control group ($53.9 \pm 9.5°$ vs. $48.18 \pm 8.3°$; $p = 0.012$, 3.9 ± 4.1 vs. 2.03 ± 1.8 mm; $p = 0.018$, respectively). The LBP visual analog scale value was also significantly higher in the urinary incontinence group (5.09 ± 2.3 vs. 1.7 ± 1.8, respectively, $p < 0.0001$). The LL angle showed a positive correlation with pelvic obliquity ($r = 0.321$, $p < 0.01$) and lumbar blade ($r = 0.472$, $p < 0.01$) and a negative correlation with lumbar spine range of motion. Pelvic tilt was positively correlated with pelvic torsion ($r = 0.649$, $p < 0.01$), low back pain ($r = 0.369$, $p < 0.01$), and pubic-supporting deformity ($r = 0.269$, $p < 0.01$). The author and colleagues concluded that women with urinary incontinence were more likely to have sagittal lumbopelvic position changes and higher lumbopelvic posture visual analogue scale scores. These results suggest the need to assess lumbopelvic position in women with urinary incontinence [12].

According to another author [13], who conducted a systematic review and meta-analysis to examine common static postural parameters in participants with and without low back pain (LBP). A systematic search was performed in PubMed, CINAHL, Embase, and SCOPUS databases. Observational studies comparing static postural measures (eg, lumbar lordosis) in participants with and without LBP were included. Two independent reviewers performed screening, data extraction, and quality assessment. Methodological

quality was assessed using the Joanna Briggs Institute Critical Appraisal Tools. In this author's studies, included in review = 46 (5097 LBP; 6974 controls); meta-analysis = 36 (3617 LBP; 4323 controls). The quality of the included studies was mixed. Pelvic tilt was statistically significantly higher in LBP participants compared to controls (n = 23; 2540 LBP; 3090 controls; SMD: 0.23, 95%CI: 0.10–0.35, $p < 0.01$, $I2 = 72\%$). Lumbar lordosis and sacral slope may be lower in LBP participants; pelvic tilt may be higher in this group; both were not statistically significant and heterogeneity between studies was high. Thoracic kyphosis and leg length difference showed no difference between study groups.

Elabd A.M, Elabd O.M. [5] studied the relationship between the forward head position and the sagittal position of the lumbopelvic region in elderly people with chronic low back pain. They also monitored using lateral fluoroscopy. In their opinion, poor posture creates abnormal stress and strain in many structures of the spine, which are considered predisposing factors for chronic mechanical low back pain. The aim of their work was to study the relationship between pain intensity, forward head position (reduced craniovertebral angle) and sagittal position of the lumbopelvic region (pelvic tilt angle, pelvic tilt, sacral tilt and lumbar lordosis) in patients with chronic mechanical low back pain. A cross-sectional correlation study was conducted involving one hundred patients. Standardized lateral standing radiographs were analyzed to measure the spinopelvic angles. The obtained data were analyzed using correlation coefficients and regression analysis [5]. Lumbar lordosis had very strong positive correlations with each pain intensity and sacral slope. Pain intensity had a strong positive correlation with sacral slope. Moderate positive correlations were found between pelvic tilt and craniovertebral angle. Moreover, pelvic morbidity had weak positive correlations with each sacral tilt and pelvic tilt. Negative correlations were strong between pelvic tilt and each pain intensity, lumbar lordosis, and sacral tilt. Craniovertebral angle had moderate negative correlations with each pain, lumbar lordosis and sacral slope. However, pelvic morbidity had no association with pain, craniovertebral angle and lumbar lordosis. Overall, the association of demographic data and measured variables had a significant impact on the pain prediction model using a multiple regression equation. They accounted for 76.60% of the variance in pain. The authors argue that abnormal posture in the spine and pelvis is associated with chronic mechanical low back pain. In patients with chronic mechanical low back pain, there is a significant association between pain intensity, anterior pelvic vertebra and sagittal position of the lumbopelvic region.

Some researchers [11] have defined anatomical reference markers used in surface topography using optical measurements; defined the parameters used in optical measurements. Twenty-three studies were included for qualitative synthesis. The most frequently used anatomical reference markers were: prominence vertebra (C7 or T1), posterior superior iliac spines (PSIS), and sacrum (S1). The parameters for assessing AIS using surface topography were: spine tilt angle (similar to Cobb), humpback, thoracic kyphosis angle, lumbar lordosis angle, pelvic tilt, spine length, apex of curvature, C7-S1 distance (frontal plane), and C7-S1 offset (sagittal plane). The data from eleven studies were meta-analyzed and demonstrated the correlation of surface topography with radiographic studies and the reproducibility of surface topography in the sagittal and frontal planes. The results of this study recommend a protocol for the use of the equipment. The studies analyzed suggest using only four markers for anatomical reference assessment. AIS can be assessed using nine parameters. Surface topography correlates with radiography when comparing the angle of the spine (Cobb angle), the angle of thoracic kyphosis, and the angle of lumbar lordosis.

According to the results of the studies by Frerich J. M., Hertzler K., Knott P., and Mardjetko S., patients with adolescent idiopathic scoliosis (AIS), radiographic observation is the gold standard for assessing spinal deformity, but has negative long-term consequences [6]. The Formetric 4D surface topography system was compared with standard radiography as a safer option for assessing the condition of patients with AIS. The study involved 14 volunteers with a typical body type for patients with acute ischemic stroke, who underwent 30 repeated measurements using the Formetric 4D device, after which the reproducibility of the results was assessed. Sixty-four patients with acute ischemic stroke were then included in the study during routine clinic visits. The assessment included standard radiographs and surface topography measurements. A comparative analysis was conducted. When the authors assessed the results of repeat scans performed on the same day, a standard deviation of ±3.4 degrees was found for the scoliosis curve measurements, and the reliability coefficient (Cronbach's alpha) was very high (0.996). Cobb angles measured with Formetric 4D differed from radiographic results by an average of 9.42 (lumbar) and 6.98 (thoracic) degrees, and the correlation between the two measurements was high (95% confidence interval [CI]): 0.758 (lumbar) and 0.872 (thoracic), respectively. The researchers concluded that the Formetric 4D is comparable to radiography in terms of test-retest reproducibility [6]. Although this device does not accurately predict the magnitude of curvature, its predictions correlate well with Cobb angles determined from radiographs. It can be used with confidence to monitor patients with acute ischemic stroke (AIS). Mehta, B. et al. in their previous studies examined the correlation and reliability of various devices and methods, such as the moiré method, raster stereography, motion capture and ultrasonography, compared with radiographs, which are the "gold standard". However, the existing literature focuses on the description of the equipment used in these studies, which is primarily due to its novelty and limited availability [9,10,14]. Notably, these studies did not compare different surface topography (ST) methods. The lack of comparisons may be due to factors such as clinical acceptance, equipment availability, and continued reliance on radiographs for the diagnosis and monitoring of scoliosis.

In conclusion, surface topography is a reliable and cost-effective non-invasive method that is an alternative to radiation imaging to aid in the diagnosis and potential screening of AIS. Several scanning modalities are available, allowing PT to be used in a variety of clinical settings. In addition, surface topography demonstrates inter- and intra-rater reproducibility in the sagittal plane and intra-rater reproducibility in the frontal plane. Surface topography is a non-radiotherapy-based imaging modality that provides important information for the evaluation of patients with adolescent idiopathic scoliosis (AIS). However, its use is not standardized, which limits its utility.

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