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Postural assessment with the moiré technique in dialyzed patients

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Chronic kidney disease (CKD) patients have limited mobility. A disease that lasts for many years may harm the musculoskeletal system. Knowledge about changes in body posture in these patients is essential in preventing its degradation. In this work, we wanted to draw attention to the changes in the spatial arrangement of the spine and the entire torso in dialysis patients. The study group consisted of 22 female and 32 male dialysis patients. The posture was examined using the moiré projection technique with a portable Computer-Aided System for Posture Assessment which calculated 82 angular and linear parameters of the spine, scapulae, and pelvis in the frontal and sagittal planes. A significant sexual dimorphism was observed for each spine segment. Asymmetry of the scapulae and pelvis was observed in both sexes. Abnormalities may help to establish an accurate exercise plan for dialysis patients. Proper stimulation of the locomotor system can prevent further degradation of body posture. (Folia Morphol 2024; 83, 2: 426–434)

Keywords: body posture, moiré technique, dialyzed patients, kidney transplantation, physical activity, public health, chronic disease

INTRODUCTION

A correct posture is one that ensures a harmonious and effortless arrangement of body parts in relation to the long axis of the body and optimal functioning. When correct posture is held, individual segments of the body ensure smooth movements and stable support with the least energy required [28, 43, 57]. The type of posture depends not only on sex but also on the stage of ontogenetic development and environmental conditions [44, 64].

Freedom of movement and stable posture are ensured by the spine [21, 31, 37, 44, 47, 62, 69]. Each change in the arrangement of one section of the spine in relation to another section affects individual parts of the skeleton, both those closer and distant from the deformed region. For example, increased cervical lordosis results in a compensatory increase in thoracic kyphosis and lumbar lordosis [44, 61, 64]. Increased thoracic kyphosis leads to a more oblique positioning of the ribs, flattening of the chest, relaxation of the abdominal muscles, and greater pelvic anteversion. Incorrect posture affects not only the skeletal system, but also the function of other anatomical systems of the human body. One of them is the respiratory system. Asymmetric, pathological shape of the chest causes changes in its mobility, which disturbs the respiratory mechanism and deteriorates conditions for the function of the lungs. Scoliosis can lead to the dislocation of organs of respiratory systems, digestive or urinary system. Change in the position of spinal segments deteriorates conditions of the nervous system function by disturbing the coordination, as well

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as the static and dynamic balance of the body [18, 44, 60, 64].

Postural disorders are caused by natural aging associated with the degeneration of skeletal structures, overload resulting from unhealthy behaviours, disorders of the skeleton-muscular system and disorders of unknown aetiology. In the unhealthy behaviour on the top of list is forced unilateral positions, unilateral loads on the spine, incorrect lifting and carrying weights, prolonged sitting and standing in a leaning position. Overloads create more difficult conditions for spinal work and increase the susceptibility of the spine to further overloads. It cause degeneration and deformation of skeletal and articular structures and faster wear [37, 44, 47, 55]. Postural disorders and their consequences in the skeletomuscular system trigger a chain reaction and accumulate [31, 37, 44, 47, 69].

In patients on dialysis, posture is affected by age-related factors, primary disease and comorbidities, but is also strongly influenced by a sedentary lifestyle. Patients on dialysis are particularly predisposed to sedentary behaviour. They spend about 12 hours each week in a supine or semi-supine position during haemodialysis. Most patients are transported to a dialysis centre, which makes the time spent in a forced sitting position even longer. Only a small percentage of patients work [20, 21, 24, 40, 44], and the majority of patients significantly reduce their physical activity [2, 26, 35, 49, 56] not only on days of dialysis, but also on days between dialysis sessions [21, 23]. Dialysis patients spend about 70% of their time lying down [7]. The level of basic types of physical activity such as walking or standing is approximately 30% lower than in the control group [21], only 34.5% of patients declared regular physical activity, and 35.4% watched their normal body weight [22, 42, 58].

All these factors increase the risk of postural disorders in dialysis patients, most of all reduction of correct curvatures of the spine and aggravation of the existing defects [56].

The aim of the study was to assess posture in dialysis patients and to further use findings for the creation of corrective exercise plans.

MATERIALS AND METHODS

The study group consisted of 54 patients treated with dialysis in a dialysis centre of the Department of Internal Diseases and Nephrology, Independent Public Teaching Hospital No. 2 PMU in Szczecin, al. Powstańców Wielkopolskich 72. The study protocol was approved by the Bioethics Committee PMU, decision no. KB-0012/161/17 of 18 December 2017. Participation in the study was voluntary, and each patient gave written informed consent.

The study group consisted of 22 women (40.7%) aged 29 to 86 years (mean 65.5 ± 14.7 SD) and 32 men (59.3%) aged 33 to 91 (mean 69.1 ± 13.6). There was no statistically significant age difference between the sexes ($p = 0.341$).

The posture of dialysis patients was examined using a portable Computer-Aided System for Posture Assessment produced by CQ Electronic System Artur Świerc whose operation relies on the photogrammetric method and the moiré effect [48, 66, 67]. This system registers the distortions of the line image and processes them into a contour map of the examined area, and then analyses the parameters in the sagittal and frontal planes. All examinations and calculations were performed by the same investigator — experienced physiotherapist to minimize the risk of the above-mentioned errors. Error of measurements was estimated.

Measurements were taken under strictly defined circumstances:

- constant distance of 2.2 m between the patient and the camera,
- constant parameters of the optical system,
- precisely levelled camera.

Before image acquisition and examination, characteristic points on the patient's back were located and marked with a special black pen:

- C7 — spinous process of the 7th cervical vertebra,
- KT — spinous process of the thoracic vertebra marking the apex of thoracic kyphosis,
- LL — spinous process of the lumbar vertebra marking the apex of lumbar lordosis,
- TL — transition point between thoracic kyphosis and lumbar lordosis,
- angle of the right scapula (Sr) and left scapula (Sl),
- posterior superior iliac spines (Mp and Ml).

Limitations of the study

Accurate postural assessment in very obese patients may be difficult because the shape of the spine on the skin covered by a thick layer of adipose tissue may significantly differ from the actual shape of the spine. In obese patients it is more difficult to locate and mark reference points that are analysed by the posture assessment system. Acquisition of data may

Table 1. General length and height of the spine and BMI of dialysis patients. Comparison between males and females with p value of U Mann-Whitney test

Trait	All group			Men			Women			p
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3	
Spine length [cm]	44.6	41.6	60.8	46.9	43.5	63.6	41.3	36.5	42.8	< 0.001
Spine height [cm]	42.0	39.4	45.6	44.4	41.7	47.2	39.9	35.7	41.7	< 0.001
BMI	26.1	22.8	28.7	26.1	23.1	28.5	25.9	22.1	28.7	0.591

Table 2. Characteristics of the angle of torso tilt (ATT) and the angle of torso inclination (ATI). Comparison between males and females with p value of U Mann-Whitney test

Trait	All group			Men			Women			p
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3	
ATT [°]	–5.6	–10.9	–3.7	–6.5	–24.8	–4.6	–3.9	–6.6	0.5	0.003
ATI [°]	0.0	–1.2	1.1	0.0	–1.2	1.1	0.0	–1.2	1.5	0.993

also be problematic in hyperactive patients or those with serious developmental defects.

Inclusion criteria

Dialysis patients with stable cardiovascular and respiratory function without congenital spinal deformities who gave their consent to participate in the study. Age over 18 years. Patients who were dialyzed over one year, three times per week.

Exclusion criteria

- Congenital postural deformities,
- Circulatory and respiratory insufficiency that does not allow the patient to stand without assistance during the examination,
- No consent given by the patient.

Data processing

Acquired images were processed with software integrated with the Computer-Aided System for Posture Assessment (CQ Elektronik System), which calculated 82 angular and linear parameters of the spine, scapulas and pelvis in the frontal and sagittal planes.

Statistical analysis

Descriptive statistics were presented as mean and standard deviation (SD). Normality of data distribution was verified with the Shapiro–Wilk's W test. Comparisons of obtained parameters between sexes were made with the Mann-Whitney's U test. Qualitative features were presented as numerical values and percentages. To compere those data, the Chi^2 test was used. Results were considered statistically significant with $p < 0.05$.

RESULTS

The general length and height of the spine and BMI of dialysis patients were characterized. There were significant differences in the length ($p < 0.001$) and height ($p < 0.001$) of the spine between sexes, which is associated with anatomical aspects of sexual dimorphism. Although, there was no significant difference in BMI between the sexes ($p = 0.591$) (Table 1).

Two parameters describing the position of the entire trunk in the sagittal and frontal planes were analysed, the angle of torso tilt (ATT) and the angle of torso inclination (ATI), respectively. In Table 2, values of the angle of torso tilt (ATT) and the angle of torso inclination (ATI) were presented. Torso tilt (ATT) was observed forward (–n°) or backward (+n°). The inclinations to the sides (ATI), was observed to the right (+n°) or to the left (–n°), but they were also observed straight (0°). The distribution of these values is presented in Table 3.

Additional parameter, which indicate asymmetry or lateral deviation of the whole spine is the number of arches of the spine. It is defined as a number of spinal intersections with the line C7–S1. There was statistically significant difference of that number between sexes ($Chi^2 = 9.86$; $df = 2$; $p = 0.008$). Results are summarized in Table 4.

There have been analysed parameters related to each sections of the spine and their curvatures in

Table 3. Prevalence of deviations from the norm of the trunk position

Trait		All group		Men		Women	
		n	%	n	%	n	%
ATT	Forward	47	87.0	31	96.9	16	72.7
	Backward	7	13.0	1	3.1	6	27.3
		n	%	n	%	n	%
ATI	Right	25	46.3	15	46.9	10	45.5
	Left	24	44.4	14	43.8	10	45.5
	Straight	5	9.3	3	9.4	2	9.1

Table 4. Numbers of arches of the spine in dialysed patients

Number of arches	All group		Men		Women	
	n	%	n	%	n	%
0	8	14.8	5	15.6	3	13.6
1	35	64.8	25	78.1	10	45.5
2	11	20.4	2	6.3	9	40.9

sagittal plane (cervical lordosis, thoracic kyphosis and lumbar lordosis), and inclination of pelvis in frontal plane. Statistics of these parameters are presented in Table 5.

The horizontal line connecting acromions indicated asymmetry of shoulders in frontal plane. Similarly, the horizontal line connecting inferior angles of scapulae revealed the asymmetry of scapulae. Both parameters are described in Table 6. Additionally, Figure 1 presents an image of a patient with asymmetry of scapulae as an example.

DISCUSSION

In recent years, many significant changes have been introduced in the assessment of postural disorders. There has been a gradual shift from techniques relying on a subjective visual assessment to objective methods based on angular and linear measurements [13, 41, 45]. Mechanical devices, such as the *sphero-*

Table 5. Characteristic of cervical lordosis, thoracic kyphosis and lumbar lordosis of the spine and angle of pelvic tilt. Comparison between males and females with p value of U Mann-Whitney test

Trait	All group			Men			Women			p
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3	
Depth of cervical lordosis [mm]	6.2	0.8	15.7	11.6	3.3	18.2	1.7	0.0	6.6	0.005
Length of cervical lordosis [mm]	29.3	23.0	37.4	27.8	21.1	37.0	31.2	27.8	45.1	0.054
Angel of thoracic kyphosis [°]	153.1	83.6	165.5	153.7	90.0	167.7	153.1	76.5	163.2	0.017
Depth of thoracic kyphosis [mm]	26.8	11.7	46.3	18.0	9.9	37.3	38.0	20.9	215.3	0.018
Apex of thoracic kyphosis [mm]	147.3	124.7	170.8	153.5	127.6	175.1	139.2	117.0	160.2	0.113
Area of thoracic kyphosis [mm^2]	900.0	0.0	4365.0	0.0	0.0	2769.0	3341.5	19.0	5705.0	0.006
Length of thoracic kyphosis [mm]	247.1	35.2	323.4	237.4	22.1	283.3	266.3	237.0	379.7	0.010
Angel of lumbar lordosis [°]	164.1	144.9	175.5	165.6	148.6	176.3	152.1	144.3	171.3	0.205
Depth of lumbar lordosis [mm]	8.5	2.3	17.6	8.8	3.6	11.8	5.9	1.5	159.7	0.048
Apex of lumbar lordosis [mm]	63.8	48.0	72.9	64.8	54.7	77.2	61.9	39.3	72.9	0.303
Area of lumbar lordosis [mm^2]	107.5	6.0	818.0	79.5	23.0	589.5	360.5	1.0	1682.0	0.443
Length of lumbar lordosis [mm]	216.2	72.1	554.4	514.9	141.3	556.6	143.1	50.3	393.4	0.048
Angle of pelvic inclination [°]	0.0	–1.2	1.6	0.0	–1.8	1.4	0.0	–0.6	2.4	0.633

Table 6. Characteristics of position of upper limb girdle. Comparison between males and females with p value of U Mann-Whitney test

Trait	All group			Men			Women			p
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3	
Angle of shoulder inclination [°]	2.4	–3.8	10.6	1.5	–4.3	8.6	3.4	–3.8	13.4	0.993
Difference of the height of inferior angles of scapula [mm]	–1.0	–8.6	4.8	–2.9	–10.1	8.7	–1.0	–5.8	3.8	0.853

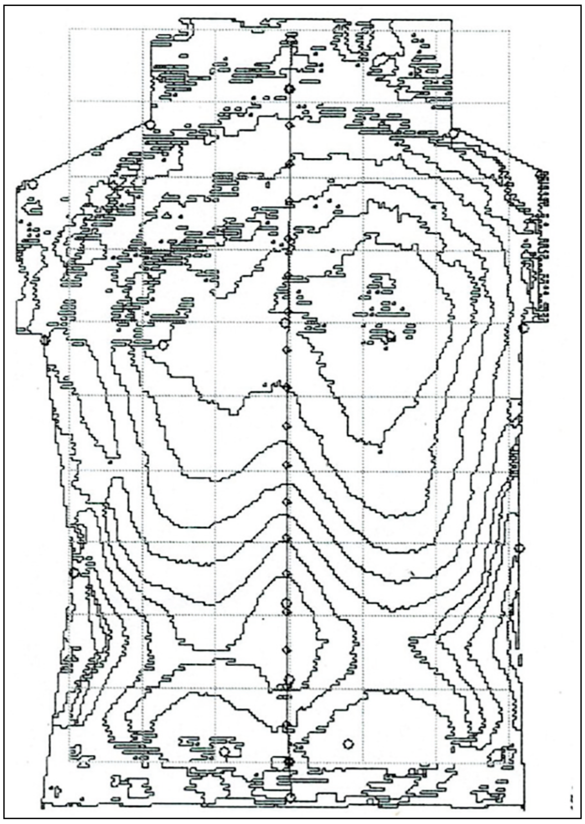

Figure 1. Asymmetry of shoulders and scapulae.

dorsimeter designed by Wolański, a posture meter-S, or kypholordosometer [10–12, 33, 59, 63] are increasingly often replaced by systems based on photometric techniques, e.g. Chiro Vision, Posturocheck or those based on three-dimensional analysis, e.g. moiré projection or ISIS [28, 36, 66, 68]. In our study posture was analysed using the Computer-Aided System for Posture Assessment from CQ Elektronik System [48] operating based on the moiré projection technique. This image is achieved by overlapping two contour line patterns. These patterns are called grids or rasters. The interference effect is most often seen as a new pattern of contour lines called moiré fringes. The moiré fringes, like the contours on a topographic map, show the actual shape of the analysed object [66]. The CQ Elektronik System offers a precise, objective and non-invasive measurement and evaluation of posture. Due to the high accuracy of the measurement, postural disorders can be diagnosed at the early stage of their formation. This system allows for static testing (3D analysis of the spine curvature, position of scapulas, the inclination of the rib hump), dynamic testing by recording sequences of movements, e.g. the range of motion in the joints, corrective testing, e.g. spinal response to a forced correction of the pelvis, corseting, kinesiotaping, as well as comparative testing, e.g. monitoring of changes in the spine curvature at short time intervals.

The computer-aided system for the detection of postural deformities allows for rapid and repeatable measurements, with a printed report on the analysis of selected parameters. An important advantage of this method is the fast acquisition of the patient's image, which prevents fatigue of the postural muscles. The patient can maintain a natural posture during examination, and the investigator can capture and document the image of this posture. Importantly, the moiré technique allows for the simultaneous measurement of all the assessed parameters based on the 3D arrangement of individual parts of the body [8]. A large area of the body can be assessed at the same time, not only the spine, but also the position of scapulas, the shoulder line, and the pelvic line [36]. Studies comparing three diagnostic methods: moiré projection, radiography and clinical examination revealed a 94% agreement in the detection of scoliosis [36, 37, 51–53]. With such a high consistency of results, the moiré photogrammetry can limit the use of X-ray examination to cases that absolutely require radiological evaluation. Screening tests can be performed using a method that is safer for health [36–38, 51–53].

Like any diagnostic technique, examination employing moiré photogrammetry also has some limitations. For example, errors of measurement might result from the design of the apparatus, instability of testing circumstances, and differences in the experience of investigators. Anthropometric reference points on the body can be marked with an accuracy of 2 mm. Some problems with marking these points may occur in overweight or obese patients. Errors may occur when positioning the patient for examination, as well as during data processing. In our study, there were no problems with marking reference points on the patient's skin. Most of the patients had normal body weight or were overweight in terms of BMI. About 22% of subjects had class 1 obesity. There were no patients with class 3 obesity.

After analysing the possibility of using various methods to assess posture in dialysis patients, the moiré technique was chosen as the most objective and the least inconvenient for patients.

Because posture may be influenced by many factors, such as testing station, type of lighting, contrast, time of day, or physical status of the patient [4, 66, 67], postural assessment was performed under the same standard circumstances for all patients.

All examinations and calculations were performed by the same investigator to minimize the risk of the above-mentioned errors. Similarly to Mrozowiak and Strzecha [36], the balanced type of posture (class RII) according to Wolański [64], with the angle of thoracic kyphosis and lumbar lordosis within the normal range, was regarded in our study as the most correct.

Computer-aided postural assessment performed in the group of dialyzed patients detected the following postural disorders: abnormalities of the shoulder line — asymmetry of scapulae and shoulders, rotations and asymmetry of the pelvis, lateral *convexities* of the spine (to the right or left, or both left and right in some cases), increased or reduced curvatures of the spine (thoracic kyphosis and lumbar lordosis), and changes in the position of the cervical spine.

Significant differences were observed between women and men in terms of thoracic kyphosis (inclination of the upper section of thoracic kyphosis, depth of thoracic kyphosis, area of thoracic kyphosis, with significantly larger changes found in women), inclination of the pelvis (more frequent to the right in men, and to the left in women) and pelvic rotation (less significant in men than in women), and torso tilt (significantly greater tilt to the left in men).

Walaszek, Kasperczyk and Borowiec [51] analysed differences in posture between 14-year-old boys and girls. They reported significant differences in several parameters: thoracic kyphosis angle, higher position of the left lower scapula angle, lower position of the left waist triangle, asymmetry in the height of the posterior superior iliac spines and the maximum deviation of the spine from the C7-S1 straight line to the left side. Walaszek [53] also observed a correlation between an increase in body weight and an increase in the forward tilt of the torso, as well as reduced lumbar lordosis.

Most postural disorders in older adults and the elderly result from natural ageing processes. These processes lead to the destruction of the spinal structures — compression and degeneration of intervertebral discs, degeneration of the articular surfaces of the vertebrae, and changes in the quality and quantity of bone tissue in the spine. The type of work and lifestyle have a great influence on the spine's health. Behaviours that have the strongest effect on the development of deformities are unilateral loads on the spine, forced positions (sedentary or standing work), work in a leaning position, and incorrect lifting and carrying weights. These factors aggravate structural changes in the relevant sections of the spine and cause deformations [31, 37, 44, 47, 64, 69]. Correct posture depends on postural hygiene and the correct tone of the muscular corset, which must be strengthened by physical activity [18, 32, 44]. In dialysis patients, apart from the above-mentioned general factors (age, underlying disease and comorbidities, type of work, lifestyle before dialysis), the current sedentary lifestyle has a very strong influence on the posture. Haemodialysis contributes to the preservation of incorrect posture through forced sitting or lying position during the procedure. Patients spend on average 12 h per week in a lying or sitting position during dialysis [20, 21, 23, 24, 40]. In addition, because of chronic kidney disease, patients are very often forced to change their lifestyle: give up work, favourite activities, hobbies or sports, change habits, or give up recreation [3, 4, 9, 16, 20, 21, 24, 34, 38, 40, 44]. Dialysis therapy affects the daily life of patients in physical, emotional and social aspects [1, 27, 56].

Reduction in the level of physical activity usually begins in the first phase of chronic kidney disease and gradually progresses. The major causes of this appear to be anaemia and impaired function of skeletal muscles, including their atrophy and sarcopenia [14, 15, 17, 19, 20, 34]. The negative effects of age-related sarcopenia and kidney disease are combined in this case. Gołębiewski et al. [20] observed impaired muscle function in 50% of the studied patients. Seto, Kimura, Matsunaga et al. [43] observed that patients undergoing dialysis experience substantial decreases in muscle mass and functional muscle weakness but control of inflammation, nutritional intake may help minimize muscle mass loss caused.

Dialysis patients not only avoid regular physical exercise, but are also reluctant to undertake daily household activities [14, 15, 17, 19, 20, 34, 38]. A study by Pikus and Moczydłowska [39] revealed that as many as 85% of patients declared limiting their physical activity because of disease. Wojczyk [56] reported that 60% of patients got involved in physical activity. All of the above factors often lead to the development or aggravation of postural disorders in dialysis patients.

However, time spent on dialysis can be used to do strengthening exercises, which will help minimize the adverse effects of the disease on posture and overall fitness.

Some studies have indicated that physical activity, even physiotherapy, improves physical fitness, increases the ability to perform daily life tasks, and improves quality of life indicators [2, 5, 6, 20, 26, 35, 49, 54]. Moderate activity adjusted to the patient's capacity can improve their functioning during dialysis sessions and would also shorten the recovery time after kidney transplantation [54].

It is worth encouraging patients to find a type of physical activity suitable for them, and to do regular training. This is not easy because it requires self-discipline and motivation, but the achieved benefits improve the patient's health and quality of life [18, 22, 25, 29, 30, 50, 65]. A study by Hishii et al. [24] conducted in Japan indicated a significant relationship between an increase in the level of physical activity and the quality of life self-reported by patients.

Before introducing physical therapy, the physician and physiotherapist should assess the patient's status in terms of the indications and contraindications for it. The intensity of training should be adjusted to the patient's health and increased gradually, and the type of activity should be planned by the physiotherapist and physician to match the physical capacity and interests of the patient [8]. Exercise should be selected with consideration of cardiological status, risk of injuries, the presence of diabetes and limitations related to it [46], as well as existing postural disorders.

CONCLUSIONS

A wide range of postural abnormalities were detected in the analysed group of dialysis patients. Most of them represented the kyphotic type (with a rounded upper back) according to Wolański's classification system. Examination using the moiré projection technique allows for a three-dimensional, simultaneous, fast and multiparametric assessment of the patient's posture, which is necessary to plan personalized rehabilitation exercises. The research allows to prepare of a universal set of exercises for dialyzed patients but of course, the individual program will lead to the best correction.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

Data generated and analysed during this study are included in this article. Additional data are available from the corresponding author on request.

Ethics statement

The study protocol was approved by the Bioethics Committee Pomeranian Medical University in Szczecin, Poland, decision no. KB-0012/161/17 of 18 December 2017. The study complies with the Declaration of Helsinki.

All participants signed written informed consent and were informed about the aim, confidentiality, and procedures of the research.

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