Quantitative measurement of surface topography in postural assessment of early and middle stage Parkinson 's disease

Abstract: Objective: To explore the significance of surface topography in evaluating posture among individuals in the early to mid-stages of Parkinson’s disease (PD), a study was conducted. The research involved 49 PD patients under the age of 75 with intact cognitive function, alongside 43 age- and gender-matched healthy participants serving as controls. Demographic information was gathered for both groups. PD patients underwent spinal X-rays in a weight-bearing stance, while surface topography measurements were taken for all participants using a DIERS-4D Formetric spine analyzer. Pearson correlation analysis was used to correlate quantitative postural assessment data from surface topography measurements with postural data from fixed-point measurements of spinal plain radiographs. Independent sample T-test was used to compare differences in surface topography parameters between Parkinson 's disease patients and normal controls.

Results: A total of 92 subjects were included in the study, 49 in the PD patient group and 43 in the healthy control group. There were no significant differences in demographic information of gender, height, and weight between the two groups (all $p > 0.05$).Quantitative postural assessment data of the PD patient group were correlated with postural data measured at fixed points on plain spinal radiographs, and there was a correlation between the measured values in spinal length measurement, spinal frontal plane deviation distance, spinal frontal plane deviation angle, and pelvic tilt angle ($p \leq 0.05$).In the quantitative postural assessment data obtained from surface topography measurements, there was a significant difference between the PD patient group and the healthy control group, which was reflected in the frontal plane deviation angle, distance, and the horizontal distance between the apex of cervical lordosis and the fixed point of thoracic kyphosis, and the measured values of the PD patients were significantly greater than those of the normal control group; in the horizontal distance between the apex of thoracic kyphosis and the apex of lumbar lordosis, the measured values of the PD patients were significantly smaller than those of the normal control group ($p \leq 0.01$).

Conclusion: Surface topography measurement and X-ray measurement have the same guiding significance for posture evaluation. PD patients have some postural abnormalities in the early and middle stages and can be quantitatively assessed using surface topography measurements.

Keywords: Parkinson's disease, surface topography measurement, abnormal posture, evaluation.

Introduction

1.1 Background

Parkinson's Disease (PD) ranks among the most prevalent disorders affecting the central nervous system [1]. This progressive condition stems from the degeneration of dopaminergic neurons within the midbrain's substantia nigra [2]. Clinically, PD is characterized by hallmark symptoms such as slowed movement, involuntary tremors at rest, and muscle rigidity [3]. As the disease advances, patients often experience a decline in postural control and walking patterns [4]. These static postural disturbances further compromise dynamic balance and mobility [5, 6]. To assess motor dysfunction in Parkinson's, the Movement Disorder Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS) serves as the benchmark evaluation tool [7]. Parkinson's Disease (PD) ranks among the most prevalent disorders affecting the central nervous system. This progressive condition stems from the degeneration of dopaminergic neurons within the midbrain's substantia nigra. Clinically, PD is characterized by hallmark symptoms such as slowed movement, involuntary tremors at rest, and muscle rigidity. As the disease advances, patients often experience a decline in postural control and walking patterns. These static postural disturbances further compromise dynamic balance and mobility. To assess motor dysfunction in Parkinson's, the Movement Disorder Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS) serves as the benchmark evaluation tool. Although there are relevant evaluations of posture in the third part, there are also some problems, such as too broad scoring criteria and too subjective scores [8].Currently, there is a lack of standardized and uniform standard definitions for abnormal posture in PD, and quantitative examination of abnormal posture has rarely been investigated. Individuals with Parkinson 's disease differ greatly in postural abnormalities individualization, as manifested by various vertebral angles [9].If X-rays are used to measure posture, there are many values to be measured, and quantitative values in terms of rotation are not easily measured [10].Postural abnormalities in Parkinson 's disease further affect balance function, causing patients to have an increased risk of falls[11,12].At present, although there are still controversies about various types of PD postural abnormalities, it is possible to reach a consensus that early recognition of PD postural abnormalities and active treatment can delay or avoid the occurrence of irreversible postural abnormalities[13].Therefore, it is necessary to quantitatively evaluate postural abnormalities in PD patients.

Surface topography measurement is a new measurement method that uses parallel rays to irradiate the surface of the posterior trunk and establishes a 3D model of the surface of the posterior trunk according to the deformation of these projected parallel rays, in order to measure and analyze each curvature of the spine and describe the postural morphology of the human body [14]. As an emerging posture quantitative measurement method, many studies have established statistical models by scanning and analyzing normal subjects and models, as well as repeated measurements of the same subjects over multiple days, thus verifying the reliability of surface topography measurement[15].

Preliminary advantages have been shown regarding the clinical utility of surface topography measurements in postural assessment, but studies on their utility in Parkinson 's disease patients have not been reported. The aim of this paper is to investigate the feasibility of this measurement method for postural assessment in Parkinson 's disease and provide new ideas for postural quantitative detection in

Parkinson' s disease.

1.2 Hypothesis

DIERS-4D Formetric measurements allow quantitative assessment of postural abnormalities in Parkinson 's disease patients.

1. Materials and Methods

1.1 Study Subjects

Patients with primary Parkinson 's disease who presented to Parkinson' s Medical Center, Beijing Rehabilitation Hospital, Capital Medical University from April to July 2022, Patient inclusion criteria：(1) Patients met the International Movement Disorder Society (MDS) diagnostic criteria for primary Parkinson 's disease, aged less than 75 years, male or female. (2) Patients with stable vital signs, Hoehn and Yahr stage 1-3 (open stage), except for serious complications and complications. (3) Mini-mental state examination (MMSE) > 24 points for those with middle school education or above; > 20 points for those with primary school education. (4) Able to stand for more than 20 s without support. Exclusion Criteria: (1) Severe cognitive impairment affecting comprehension instructions. (2) Patients who are unable to stand due to various reasons. (3) Those who cannot cooperate with the completion of the assessment due to various reasons. (4) Patients with various previous spinal and skeletal problems.

Inclusion criteria for healthy subjects: (1) Age less than 75 years, male or female; (2) Vital signs were stable, except for serious complications and complications. (3) Mini-mental state examination (MMSE) > 24 points for those with middle school education or above; > 20 points for those with primary school education. (4) Able to stand for more than 20 s without support. Exclusion Criteria: (1) Severe cognitive impairment affecting comprehension instructions. (2) Patients who are unable to stand due to various reasons. (3) Those who cannot cooperate with the completion of the assessment due to various reasons. (4) Patients with various previous spinal and skeletal problems;

Prior to the study’s commencement, all participants underwent a thorough review and received approval from the Ethics Committee of Beijing Rehabilitation Hospital, Capital Medical University (ethical approval number: 2021bky001). Additionally, every individual provided written informed consent before taking part in the research. The study comprised 49 patients—19 men and 30 women—with an average disease duration of 5.6 years, ranging from 3 to 10 years. For comparison, a control group of 43 healthy individuals was included, consisting of 18 men and 25 women. Detailed clinical information for both groups is outlined in Table 1.

Table 1. Basic information of PD patients and healthy controls

	PD group	Control group	T value	p
Number	49	43		
Gender (M/F)	19/30	18/25	-0.298	0.766
Height（cm）	164.1±7.8	160.4±25.9	0.967	0.336

Weight（kg）	67.8±17.7	66.8±15.7	0.304	0.762

As shown in the table, the detailed basic data of subjects in the two groups showed that there was no significant difference in demographic information of gender, height and weight between the two groups (all $p > 0.05$).

1.2 Study appliances

DIERS-4D Formetric Spine Meter (Model: diers formetric 4d; Germany)

Philips Digital Medical X-ray Radiography System (Model: Philips-Digitaldiagn; Netherlands)

Donghua Online Reading Measurement System

1.3 Study Methods

Clinical data collection, surface topography measurement and digital radiography were performed by the same physician and were ensured to be performed in the open state of the patient.

1.3.1 Collection of clinical data: Basic information including gender, height and weight was collected from patients and healthy controls.

1.3.2 Surface topography measurement [16]

Surface topography measurements were performed using a DIERS Formetric 4D instrument, which requires the subject to fully expose the back, stand on a platform 2 m from the projector with parallel feet and stand in a relaxed natural posture. In front of the subjects, an adjustable fixation point was provided as a visual reference according to their shoulder height, which instructed them to focus their line of sight on this fixation point during scanning to control the head position. The subjects were scanned six consecutive times before leaving the platform. During each 6-second scan, the subject was asked to stand naturally. In between scans, subjects were asked not to move from their original position on the platform.

The research findings were categorized into five distinct segments: positioning and distance, trunk and pelvic alignment, spinal landmarks, curvature assessments, and spinal irregularities. Measurements from surface topography were recorded in millimeters, percentages, or degrees, tailored to the specific metric in question. To derive the shape parameters from a sequence of images, an algorithm was employed to compute the average values of these parameters across the entire scan. As a streamlined approach to data processing, the algorithm identifies the image most representative of the mean from a set of 12 and extracts the spinal shape parameters from that particular frame.

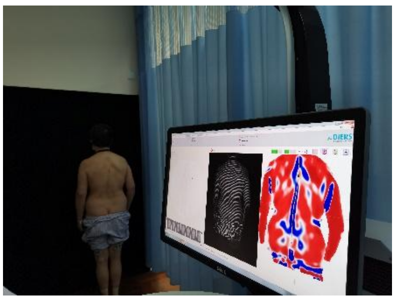

Figure 1 Surface topography measurement

1.3.3 Digital radiography

The patient was given the doctor 's advice for X-ray spine full-length film, and the radiologist performed spine full-length film photography for the patient, followed by reading using the Donghua online reading system, and selected the marker points of the seventh cervical spinous process (VP), left posterior superior iliac spine (DL), and right posterior superior iliac spine (DR) to define the total length of the spine as the midpoint (DM) of the line from the seventh cervical spinous process to the left and right posterior superior iliac spines, the frontal plane deviation angle as the angle between the midpoint of the line from the seventh cervical spinous process to the left and right posterior superior iliac spines and the plumb line through the seventh cervical vertebra, and the pelvic tilt angle as the angle between the line from the left and right posterior superior iliac spines and the horizontal line.

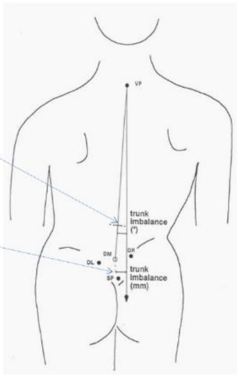

Figure 2. Measurement of overall spinal length and frontal plane deviation

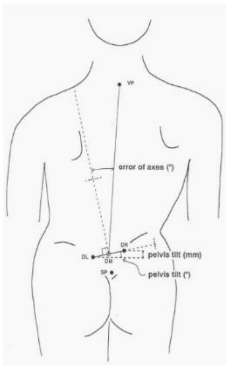

Figure 3. Pelvic tilt measurement

1.4 Statistical analysis

Statistical analysis was conducted using SPSS 26.0 software. For data that followed a normal distribution, results were presented as the mean ± standard deviation, and comparisons between groups were made using an independent sample t-test. In cases where the data did not meet the criteria for normal distribution, the median along with the upper and lower quartiles was used, and the Mann-Whitney U test was employed for group comparisons. A p-value of less than 0.05 was deemed statistically significant. Pearson correlation analysis [17] was used to correlate surface topography detection data with plain radiography measurements, and in this study, r=0 to 0.2 was considered to be not correlated or very correlated, r=0.2 to 0.4 was considered to be low-grade correlation, r=0.4 to 0.6 was moderately correlated, r=0.6 to 0.8 was strongly correlated, and r=0.8 to 1.0 was extremely strongly correlated. The significance level was set at p=0.05.

2. Results

2.1 Correlation analysis between quantitative posture of surface topography and posture data measured by radiography

Plain radiographs of the X-ray examination performed by the patient were manually measured using the Donghua online reading system, and the patient was photographed as a full-length radiograph of the spine in the weight-bearing position, therefore, we could select the dorsal marker point to measure the lateral flexion angle in the frontal plane of the patient, select the marker point Vertebra Prominens (VP), Dimple left (DL), and Dimple right (DR), define the total length of the spine as the midpoint of the line between the VP and the centre between DL and DR (DM), the frontal plane deviation angle as the angle between the midpoint of the line between the seventh cervical spinous process and the left and right posterior superior iliac spine and the vertical line through the seventh cervical spine, and the pelvic tilt angle as the angle between the line between the left and right posterior superior iliac spine and the horizontal line. It is consistent with the marking point selection in surface topography measurement method. Afterwards, correlation analysis was performed between the values related to manual measurement of X-rays and the corresponding marker point values obtained in surface topography measurements, which had a moderate correlation in the measurement of the total length of the spine (Figure 4, R = 0.556; p = 0.000), a strong correlation in the angle of deviation of the frontal plane of the spine (Figure 5, R = 0.902; p = 0.000), and a strong correlation in the distance of deviation of the frontal plane of the spine (Figure 6, R = 0.974; p = 0.000), and a low correlation in the angle of pelvic inclination (Figure 7, R = − 0.338; p = 0.018).

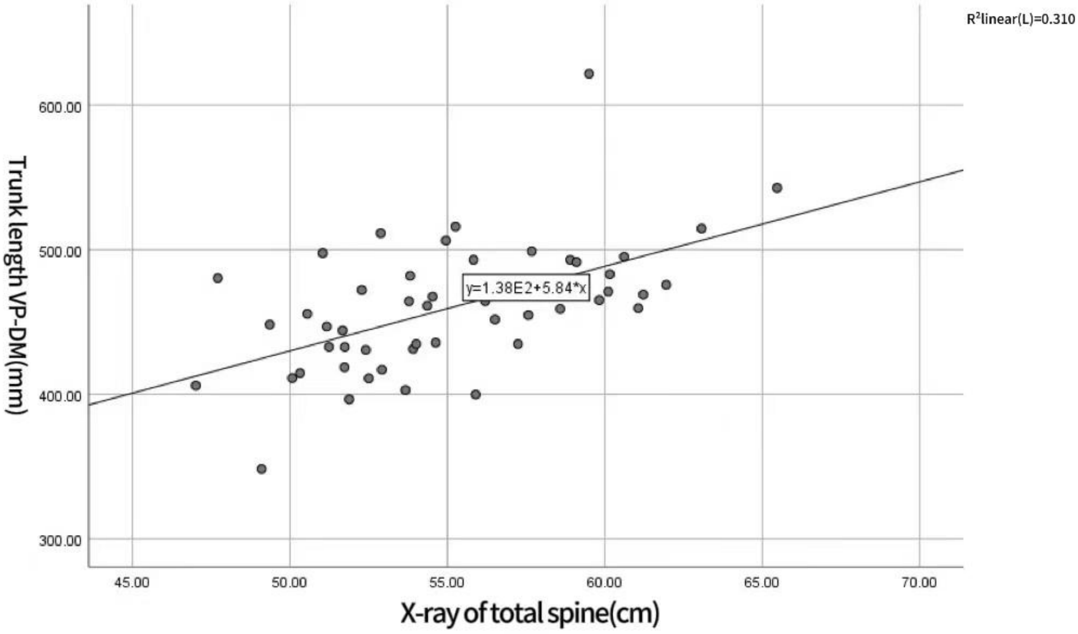

Figure 4. Spine full-length correlation analysis

R = 0.556; p = 0.000

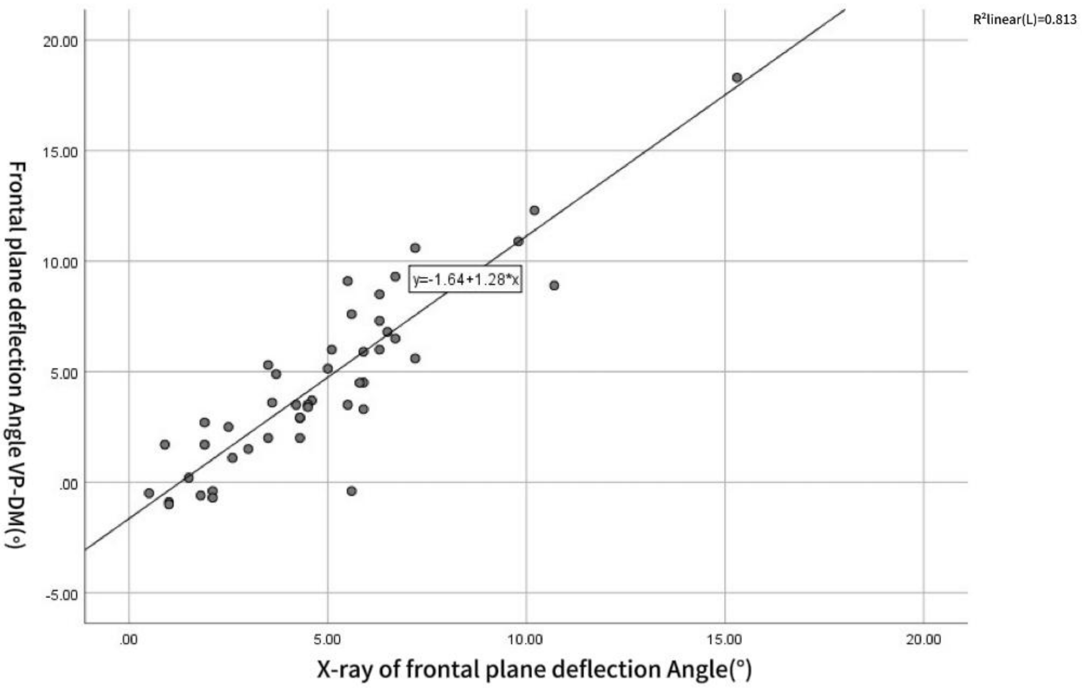

Figure 5. Correlation analysis of the angle of deviation of the frontal plane of the spine

R = 0.902; p = 0.000

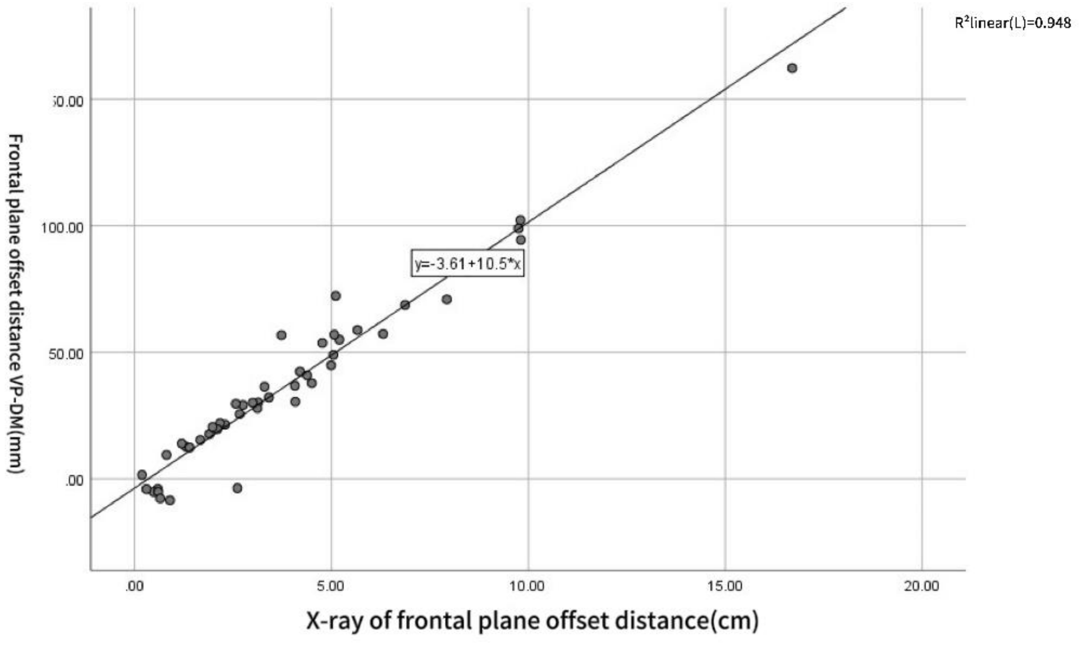

Figure 6. Correlation analysis of the deviation distance of the frontal plane of the spine

R = 0.974; p = 0.000

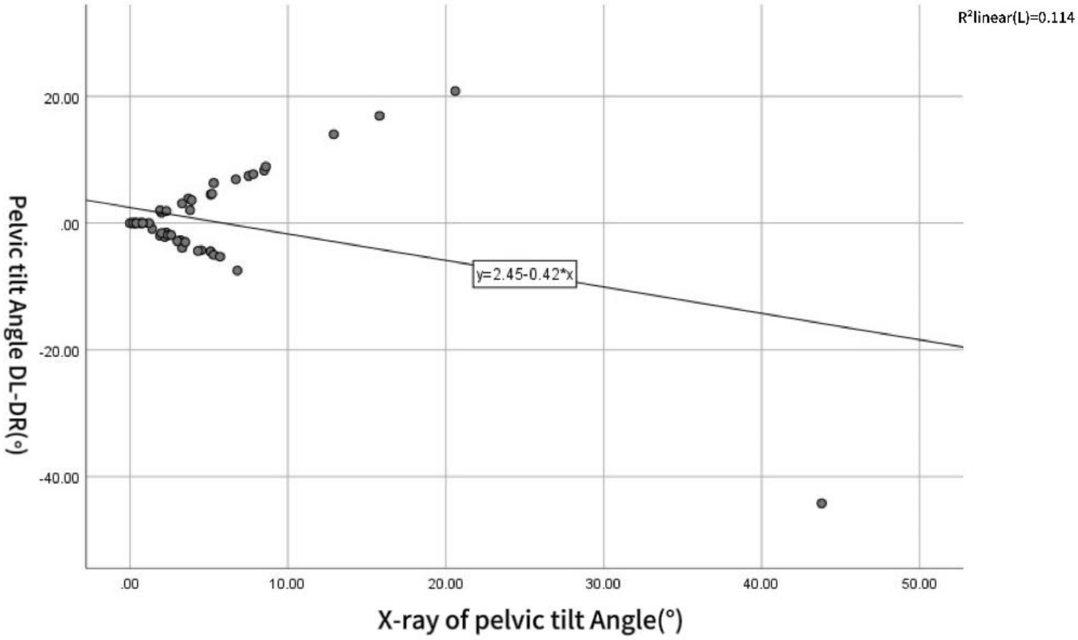

Figure 7. Correlation analysis of pelvic tilt angle

R = -0.338; p = 0.018

2.2 Surface topography measurements in PD and control groups

Table 2 Surface topography measurements in PD group and control group

	PD group	Control group	T value	p
Spine frontal plane deviation angle VP-DM_ [°]	4.75±4.03	0.95±3.12	4.996	0.000
Spine frontal plane deviation distance VP-DM _ [mm]	39.07±34.83	8.10±24.74	4.854	0.000
Horizontal distance between thoracic kyphosis apex and lumbar lordosis apex _ [mm]	32.34±20.71	41.96±14.02	-2.572	0.012
Thoracic Kyphosis Highest Point _ [mm]	-195.68±34.49	-173.63±47.94	-2.500	0.015
Horizontal distance between cervical lordosis apex and thoracic kyphosis apex _	80.97±26.81	57.57±21.73	4.557	0.000

[mm]

In surface topography, subjects performed back scans, and during six scans at six seconds each, the DIERS-4D formetric instrument collected 12 images of the posterior surface of the trunk, and from each image, 40 spine shape parameters were derived for evaluation. According to the built-in algorithm, the instrument marks the spine marker points and obtains the spine length and angle related values in each plane. In the surface topography measurements, PD patients were higher than healthy controls in the measured values of the angle, distance, and horizontal distance between the apex of cervical lordosis and the fixed point of thoracic kyphosis in the frontal plane of the spine, and lower than healthy controls in the horizontal distance between the apex of thoracic kyphosis and the apex of lumbar lordosis, and the highest point of thoracic kyphosis, and the differences were statistically significant ($p \le 0.05$).

3. Discussion

This study intends to provide a quantitative assessment of the value of posture evaluation and X-ray measurement in patients with Parkinson 's disease. Postural abnormalities in patients with Parkinson 's disease are of increasing concern, and although the mechanism by which postural abnormalities arise is not clear[18,19], previous studies have demonstrated a positive relationship between postural abnormalities and severity of the disease, and affect dynamic postural stability and increase the risk of falls in patients [20, 21]. At present, MDS-UPDRS-III is used as the gold standard for evaluating motor dysfunction in PD patients [7]. Although there are related evaluation items about posture, the grade classification is broad and subjective [22], so the specificity for the classification of abnormal posture in PD patients is poor [8]. At present, the classification criteria of postural abnormalities have not been unified, relying only on clinical symptoms and radiological examination to differentiate, the missed diagnosis rate is high, and intervertebral abnormalities are difficult to detect[23]. Therefore, quantitative analysis of posture in PD patients is particularly important.

Surface topography measurement, as an emerging method for quantitative analysis of posture, has not been investigated for specificity in PD patients, although reliability and standardized measurements have previously been confirmed [24]. Therefore, 49 patients with primary Parkinson 's disease were selected as subjects for surface topography measurement and radiological examination in order to investigate the specificity of surface topography for posture description in PD patients.

In this study, we used Donghua X-ray reading system to manually measure the X-ray examination plain film of patients, and the patients were photographed as the full-length X-ray radiography of the spine in the weight-bearing position. Therefore, we selected the same dorsal marker point to measure the lateral flexion angle on the frontal plane according to the dorsal marker point selection method in the surface topography method. Afterwards, the correlation analysis was performed between the values related to manual X-ray measurement and the corresponding marker point values obtained in the surface topography measurement, which had a moderate correlation in the overall length measurement of the spine ($R = 0.556$; $p = 0.000$), a strong correlation in the frontal plane deviation angle of the spine (R = 0.902; p = 0.000), a frontal plane deviation distance of the spine (R = 0.974; p = 0.000), and a low correlation in the pelvic inclination angle (R =−0.338; p = 0.018). It can be seen that the marker points selected for measurement after radiography are correlated with the numerical results of the same marker points of the spine directly measured by the surface topography method. Therefore, it can be shown that both surface topography measurement and radiography measurement can measure the relevant frontal plane lateral flexion values on the spine, and both measurements have the same effect. Compared with manual measurement after X-ray radiography, surface topography can not only obtain the relevant spinal values in the frontal plane, but also measure the parameters in the sagittal and horizontal planes, and describe the spinal morphology more three-dimensional stereoscopically. At the same time, surface topography is more convenient and efficient than X-ray measurement, has no radioactivity, and is easier to be accepted by testers.

The results of comparative analysis of surface topography measurements between patients and healthy controls showed that the angle and distance of frontal plane deviation measured by surface topography, the horizontal distance between the apex of cervical lordosis and the fixed point of thoracic kyphosis, and the horizontal distance between the apex of thoracic kyphosis and the apex of lumbar lordosis were significantly different between PD and healthy controls, which could indicate that these postural values were specific in the signs of Parkinson's disease patients. Among the surface topography measurements, PD patients were higher than healthy controls in the measured values of the angle, distance, and horizontal distance between the apex of cervical lordosis and the fixed point of thoracic kyphosis in the frontal plane of the spine, which indicated that Parkinson 's patients were more likely to have lateral flexion of the trunk, as well as flexion of the upper thoracic segment compared with healthy controls; at the horizontal distance between the apex of thoracic kyphosis and the apex of lumbar lordosis, the measured value of the highest point of thoracic kyphosis was lower than that of healthy controls, and it was also further demonstrated that this group of tested Parkinson' s patients compensated flexion of the upper thoracic segment with reduced physiological curvature of the thoracolumbar segment to maintain body balance. These conclusions are also consistent with previous expert consensus on the cut-off value of axial postural abnormalities in Parkinson 's disease [25], and patients with Parkinson' s disease may present with one or more axial postural abnormalities, which are often manifested in the frontal and sagittal planes, excessive postural abnormalities in the sagittal plane can progress to trunk lordosis with the thoracic spine as the fulcrum or the lumbar spine as the fulcrum, and severe lateral flexion in the frontal plane will progress to Pisa 's syndrome.

From the above results it can be concluded that surface topography measurements can provide quantitative indices of postural performance in PD patients and have scientificity equivalent to radiological examinations. Compared with manual measurement after marking points on X-ray plain film, surface topography measurement is more convenient and efficient, and at the same time, surface topography measurement can obtain more values of vertebral rotation. These values can quantify the static and dynamic postural performance of PD patients and help the tester describe the posture of the subjects more objectively and precisely. In the future, surface topography measurement and analysis can be considered to evaluate the postural status of patients with Parkinson 's disease, providing new ideas for postural assessment of patients with Parkinson' s disease and better evaluating postural changes in patients with Parkinson 's disease. To provide more postural data for more accurate prediction of fall risk in Parkinson 's disease patients through postural performance.

The following shortcomings remain in this study: First, the inclusion criteria for this study are stricter, the general symptoms of the subjects are mild, and the course of the disease is short, the posture itself is relatively mild, the mean UPDRS-III posture score is 1 (1-2), between the slight abnormal posture and the improved posture after reminders, the degree of abnormal posture of the patients is generally low, so the specificity of the relevant values in surface topography measurement is low. In addition, all patients were evaluated and tested during the open period, and the effect of drug factors on the functional status of patients was not considered. Results may therefore be biased.

In the future, we may consider relaxing the inclusion criteria of subjects, increasing the sample size, considering H-Y stage 4 patients, comparing the different performance of posture and stability of patients in each stage; adding testing at the off stage to explore the effect of drug factors on their functional status. Making the findings more generalizable.

4. Conclusions

Surface topography measurements can quantitatively assess posture in Parkinson 's disease patients. It can be widely used in the quantitative assessment of posture in Parkinson 's disease. It may also be considered in the future as an indicator to quantify postural improvement in Parkinson 's disease.

5. References

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