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Standard reference values of the upper body posture in healthy young female adults in Germany: an observational study

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ABSTRACT

Objective Classifications of posture deviations are only possible compared with standard values. However, standard values have been published for healthy male adults but not for female adults.

Design Observational study.

Setting Institute of Occupational Medicine, Social Medicine and Environmental Medicine, Goethe-University Frankfurt/Main.

Participants 106 healthy female volunteers (21–30 years old; 25.1±2.7 years) were included. Their body weight ranged from 46 to 106 kg (60.3±7.9 kg), the heights from 1.53 to 1.82 m (1.69±0.06 m) and the body mass index from 16.9 kg/m² to 37.6 kg/m² (21.1±2.6 kg/m²).

Outcome measures A three-dimensional back scan was performed to measure the upper back posture in habitual standing. The tolerance ranges and CI were calculated. Group differences were tested by the Wilcoxon Mann-Whitney U test.

Results In normal posture, the spinal column was marginally twisted to the left, and the vertebrae were marginally rotated to the right. The kyphosis angle is larger than the lumbar angle. Consequently, a more kyphotic posture is observed in the sagittal plane. The habitual posture is slightly scoliotic with a rotational component (scapular depression right, right scapula marginally more dorsally, high state of pelvic right, iliac right further rotated anteriorly).

Conclusions Healthy young women have an almost ideally balanced posture with minimal ventral body inclination and a marginal scoliotic deviation. Compared with young males, women show only marginal differences in the upper body posture. These values allow a comparison to other studies, both for control and patient data, and may serve as guideline in both clinical practice and scientific studies.

INTRODUCTION

Various subjective and objective methods to quantify and analyse the body posture have been used, especially for the spinal posture. All prior methods tried to evaluate deformity in the diagnosis and treatment of spinal diseases like scoliosis.[1–4]

Strengths and limitations of this study

► Strength: large number of healthy young female participants aged 21–30 years.
► Strength: video raster stereographic quantitative analysis of the upper back posture.
► Limitation: measurement of the upper body posture only in habitual standing position, not while moving.
► Limitation: external influences (occupational environment) were not assessed which might influence the body posture.

Quantitative analytical methods enable the diagnosis of spinal curvature deviations and/or control the therapeutic effects. The methods vary by their technical complexity and clinical applicability. Roentgenograms or CT scans are frequently used for bone structure deformities, while ultrasound, inclinometer, thermal infrared imaging, scoliometer or video raster stereography are established postural measurement methods.[5–10] X-ray based methods despite their mutagenic potential still are the gold standard in diagnosis and follow-up of body posture deviations.[11–14]

Video raster stereography has recently been evaluated as an alternative method to quantify vertebral column posture and its deformities.[7 8 15–18] Guidelines for orthopaedic rehabilitation in Germany also recommend a follow-up check but do not specify the methods.[19] The three-dimensional (3D) back scan measures the body geometry between the seventh cervical vertebra and the gluteal cleft. It has high intraclass correlation coefficients and good Cronbach's alpha values for intra-day and interday reliability for all spine parameters.[17 18 20 21] Furthermore, intertester reliability is high.[17]

A 3D surface contour image of the back appears suitable to determine vertebral column deformities, but also to quantify

the effect of, for example, orthopaedic shoe insoles on the body posture.[22 23] In addition, 3D images can quantify muscular imbalances (kyphotic/lordotic deviations, differences in waist contours, rotation in the shoulder or pelvis) and control the therapeutic success of muscle training in primary, secondary and tertiary prevention.[24 25]

Due to the changing workplace environment with its increase in digital work, ever more employees work in a sitting position. Both in the workplace and in the household, this leads to a steady decrease of physical stress on the body. This lack of exercise may result in the development of muscular imbalances and increasing numbers of persons with back pain, currently estimated at 20 million people for Germany.[20] Back pain due to musculoskeletal disorders can lead to disability or early retirement. Even more frequently, rehabilitation is required to restore the capacity to work in their original occupation.

Early signs of postural disorder, that is, musculoskeletal imbalances should be detected when subjective symptoms have developed, and treated appropriately; in order to assess both diagnosis and treatment effects, quantitative classification criteria are necessary for deviations from normal posture. These deviations should be quantified, for example, in the form of (parametric or non-parametric) percentiles, similar to the Z-score or T-score of bone density.[26] However, no standard or reference values for body posture currently are published for healthy female subjects; reference values of the upper body posture for healthy men have been published only recently.[27] Also, classifications of the severity of posture deviations are only possible when deviations from standard or reference values are quantified.

This study measures the upper body posture in healthy women aged 21–30 years by a 3D back scan to provide standard values for the posture of young healthy women. These values and their variances define the normal upper body posture and its variability and may be used to categorise the results of other (orthopaedic) studies. Investigating a homogeneous group of subjects eliminate constitutional, habitual and degenerative changes that could increase both tolerance ranges and CIs.[28–31]

METHODS
Subjects and public involvement
One hundred and six female volunteers between 21 and 30 years (25.1 ± 2.7 years) participated in this study. Their body weight ranged from 46 to 106 kg (60.3 ± 7.9 kg), height from 1.53 to 1.82 m (1.69 ± 0.06 m) and body mass index (BMI) ranged from 16.9 to 37.6 kg/m² (21.1 ± 2.6 kg/m²). Six per cent of the participants were underweight (BMI <18.5 kg/m²), 87.8% of the participants had a normal BMI (18.5–24.9 kg/m²), 4.7% were overweight (BMI 25–29.9 kg/m²) and 0.9% had obesity I (BMI 30–34.9 kg/m²) according to the WHO weight classification.[32]

All subjects were healthy and free of musculoskeletal symptoms, and therefore no patients were involved.

Using a questionnaire, temporomandibular system disorders were excluded[33]; 95.3% of the subjects reported to be right-handed and 4.7% were left-handed; 72.6% of the participants were students, 27.4% employees in different occupations (dentists, physicians, teachers, office workers).

All volunteers were healthy (no patients involved) and informed about the study design before giving written informed consent.

Measurement system
A 3D back scan was performed to quantify the upper back posture while standing, using the back scan system 'MiniRot Kombi' (ABW, Frickenhausen/Germany).

In this system, a projector forms a stripe pattern on the persons bare back; this stripe pattern is captured by an LCD camera from a defined angle. One measurement lasts approximately 2 s. In this way, the back surface is represented as a phase picture which is analysed by an integrated software program reconstructing the 3D image. For calibration of the phase pictures, all test persons are marked at six defined, standardised anatomical locations (figure 1) indicating underlying bone structures. These allow the calculation of 3D parameters (figure 1) with information about rotational movements in the shoulder and pelvic area and the shape of the spine (lordotic, kyphotic and/or scoliotic postures). Artefacts may be caused by different marker placements or movements during the scan, that is, the projection of the stripe pattern on the back, and thus have to be avoided. To measure the body posture, three repeat measurements are taken within 2 min.

During a movement sequence, 15 photos were taken. The maximum picture frequency of the MiniRot Kombi system is more than 50 frames/s with a spatial resolution of 1/100 mm. The calculation of the 3D coordinates of the back surface is performed by triangulation. The system error is specified as <1 mm (manufacturer information), the reproducibility is limited by the calculations of the upper body posture defined by markers directly on the skin (<0.5 mm).

Body scans
The subjects stood barefoot in their habitual body and jaw posture about 90 cm in front of the back scan apparatus. The arms were hanging loosely; the subjects looked straight fixing the opposite wall.

Evaluation parameter
From the 3D back scan, three components were quantified: spinal area (markers on C7 and L5), shoulder area (markers at the top of the left/right scapula) and pelvis area (markers on the left/right spina iliaca posterior superior (SIPS)). The marker positions are shown in figure 1, the spine parameters are selected and calculated as described in.[27]

Statistical evaluation
All calculations were carried out using BIAS V.11.0 (Epsilon Verlag, Darmstadt, Germany). Parameter
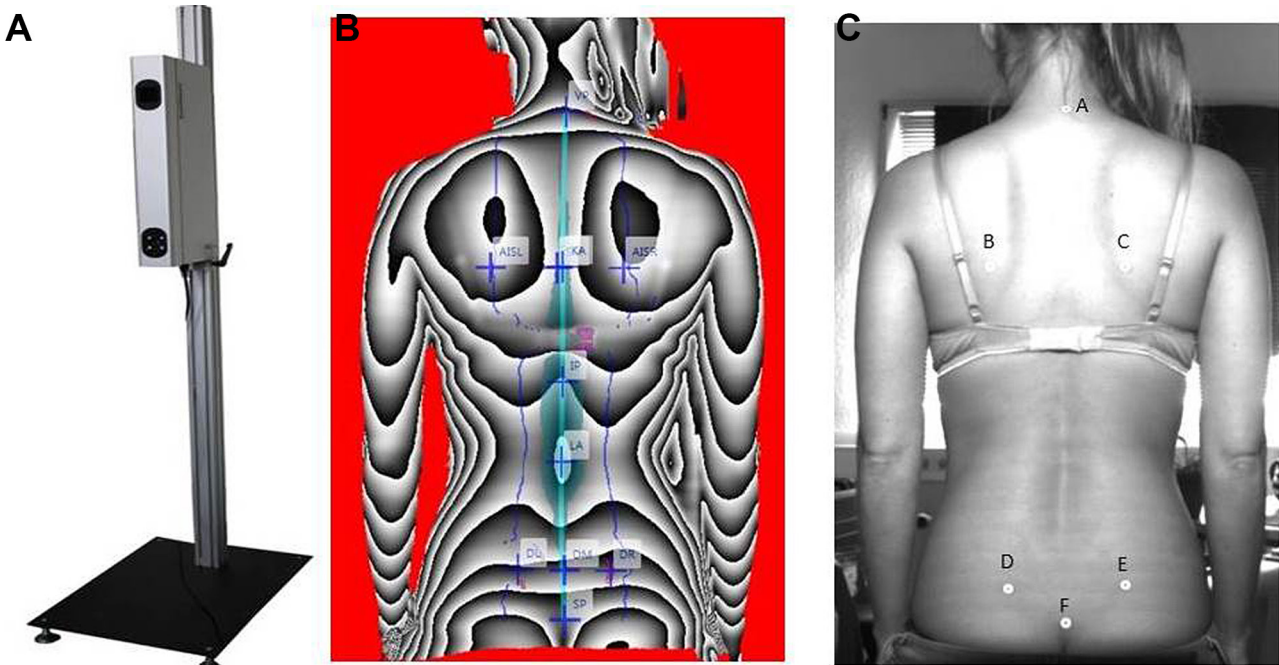
Figure 1 (A) Back scanner MiniRot Combi (ABW, Frickenhausen/Germany), (B) three-dimensional phase picture of the back, (C) marker position on the back—A: vertebra prominens (seventh cervical vertebra); B: lower scapular angle, left; C: lower scapular angle, right; D: spina iliaca posterior superior (SIPS), left; E: SIPS, right; F: sacrum-point (cranial beginning of the gluteal cleft).

distribution was tested by the Kolmogorov-Smirnov test indicating only partially normal distribution; parametric or non-parametric tolerance regions were calculated as defined by the upper and lower limits for 95% of all values (±2 SD values), being found in >95% of the examined subjects. Values within this range were considered 'normal'.

Furthermore, the two-sided 95% CI was calculated and indicated the range of the mean or median value—depending on the distribution quality—and showed the 'accuracy' of these values. For group differences, the t-test or the Wilcoxon Mann-Whitney U test was used.

RESULTS

Only the constitutional parameter 'body height' was normally distributed, whereas 'body weight' and 'BMI' were not. The median body weight was 60 kg (tolerance range 49.0–77.28 kg; CI 57 to 62 kg). For the BMI, a median of $20.7 \, \text{kg/m}^2$ was calculated, with a corresponding tolerance range from 17.99 to $27.2 \, \text{kg/m}^2$ and a CI from 20.3 to $21.3 \, \text{kg/m}^2$. For the body height, a mean value of 1.69 m was calculated with a tolerance range between 1.57 and 1.82 m and a CI of 1.68 to 1.70 m.

Handedness as a relevant parameter had been refused in advance by the t-test and the Wilcoxon Mann-Whitney U test. All parameters were not significantly different ($p \geq 0.05$).

From the back scan values, the posture of an average healthy female person was calculated (tab. 1). On average, the subjects were standing slightly inclined in the anterior line of 3.31° (tolerance range 8.12° ventrally to 1.50°

dorsally; confidence range 3.78° to the left, to 2.85° to the right).

Laterally, a minimal deviation of the frontal trunk of 0.43° to the left was seen, the CI (0.18° right to 0.67° left) included the perpendicular position; the tolerance interval ranged from 2.91° to the left, to 2.06° to the right. In compensation, the axial deviation (inclination between upper body and pelvis) was slightly tilted to the right (0.21°) with a tolerance range of ±4.5° and a CI of <1° (0.25° left and 0.66° right). This implied that there were no obvious differences in the inclination between the upper and lower body.

The angle of the thoracic bend was calculated from the distance between the vertebra prominens (VP) and the kyphosis apex and indicated the deviation from the perpendicular line. The median angle was 13.9°, confirming the expected thoracic kyphosis. Here, wider variations were seen with a tolerance range from 6.49° to 21.31°, and a CI varying from 13.19° to 14.62°. The lumbar bending angle described the deviation of the distance between the lordosis and kyphosis apex. As compared with the thoracic bend, similar variations of the tolerance value and the CIs were seen in the lumbar region, with a bending angle of 13.17° (tolerance value 7.83° to 23.06°; CI 11.90° to 14.25°).

Measurement of the lateral deviation showed a right-sided inclination of the median line by 3.92° when connecting the points VP and the centre of the pelvic markers. Both the tolerance range (0.50° and 7.33°, respectively) and the CI (3.59°/4.25°) indicated a right-sided deviation.

The rotation of the spinal column is a marker of the spinal column torsion and can be measured from the spinal processes. In our analysis, a negative value indicated a rotation to the left and a positive value, to the right. The median rotation was 4.66°, with a tolerance range between 2.04° and 12.92°, and a CI between 4.18° and 5.29°. Consequently, on average a right-sided spinal rotation was found.

The kyphosis and lordosis angle have a mean or a median of 51.66° and 46.29°, with a substantial tolerance range of approximately ±25° and a CI of about ±2°.

Shoulder parameters are valid indicators for upper body posture (tab. 1), too. The lower scapular spinae were measured by fixed markers; the interscapular distance as indicator of the variability of the upper body was 150.56 mm, with a tolerance range of 110.51–190.60 mm, and a confidence limit of 146.68–154.43 mm. The scapular height (deviation from the horizontal line) refers to a slightly lower left shoulder blade (by 1.28°),

whereas the upper and lower limit of the range markers were −22.36° and 19.81°, so that the left shoulder blade is more caudally in the lower limit and more cranially in the upper limit. The same variation is shown by the data of the CI, with values of −3.32° (left scapula higher) and − 0.76° (right scapula higher).

The shoulder markers illustrated the right shoulder being slightly further dorsal by 3.06°, with a tolerance range of −3.26° to 9.37° and a CI of 2.44° to 3.67°. Only minor differences were seen between the left and right shoulder blade angles, with the right shoulder 2.6° (median) more caudally.

Table 1 also compiles the pelvic parameters. The distance for the SIPS markers refers to the pelvic width, which on average is 99.56 mm (tolerance range 74.76–122.37 mm, CI 97.17 and 101.96 mm).

The deviation of the pelvic height (in degrees) from the horizontal plane is very low. Both differences in pelvic height (in mm) and deviations from the horizontal line

Table 1 Spine, shoulder and pelvis parameter: mean value, median, tolerance regions (upper and lower limit), CI (left and right limit)

	Mean value/ median	Tolerance range, lower limit	Tolerance range, upper limit	CI, left limit	CI, right limit
Spine parameter					
Trunk length D (mm)	461.31	412.95	509.67	456.64	465.99
Trunk length S (mm)	509.52	458.88	560.15	504.62	514.41
Sagittal trunk decline (°)	−3.31	−8.12	1.5	−3.78	−2.85
Frontal trunk decline (°)	−0.43	−2.91	2.06	−0.67	−0.18
Axis decline (°)	0.21	−4.45	4.86	−0.25	0.66
Thoracic bending angle (°)	13.9	6.49	21.31	13.19	14.62
Lumbar bending angle (°)	*13.17*	*7.83*	*23.06*	*11.9*	*14.25*
SD lateral deviation (mm)	3.92	0.5	7.33	3.59	4.25
Maximal lateral deviation (mm)	*−5.35*	*−12.8*	*12.38*	*−5.76*	*−0.89*
SD rotation (°)	*4.66*	*2.04*	*12.92*	*4.18*	*5.29*
Maximal rotation (°)	*9.2*	*−9*	*37.48*	*8*	*10.76*
Kyphosis angle (°)	51.66	27.91	74.42	49.37	53.96
Lordosis angle (°)	46.29	21.66	70.92	43.91	48.67
Shoulder parameter					
Scapular distance (mm)	150.56	110.51	190.6	146.68	154.43
Scapular height (°)	−1.28	−22.36	19.81	−3.32	0.76
Scapular rotation (°)	3.06	−3.26	9.37	2.44	3.67
Scapular angle left (°)	28.54	16.49	62.74	27.36	30.74
Scapula angle right (°)	31.17	10.61	73	27.2	34.62
Pelvis parameter					
Pelvis distance (mm)	99.56	74.76	124.37	97.17	101.96
Pelvis height (°)	0.76	−4.29	5.81	0.28	1.25
Pelvis height (mm)	1.34	−7.33	10.01	0.5	2.18
Pelvis torsion (°)	0.24	−6.89	7.36	−0.45	0.93
Pelvis rotation (°)	2.2	−5.72	7.34	1.49	2.76

Italic data are non-parametric values.

(in degrees) indicate a slightly higher position of the right pelvis by approximately 1° or 1 mm (tab. 4). The same applies to the pelvic torsion and rotation, so that the right iliac marker is rotated posteriorly and simultaneously tilted further ventral (mean pelvis torsion: 0.24°; mean pelvic rotation: 2.2°).

DISCUSSION

This paper presents normal values and normal ranges including tolerance and CIs for the body posture of healthy young females. Height, weight and BMI of the participants are comparable with average young German female persons,[34 35] as measured by Mensink et al[34] in over 7000 adults from the general German population. The age-matched female group from Mensink et al[34] was 3.20 cm smaller, 4.92 kg heavier and thus also had a slightly higher BMI by 2.58 kg/m² compared with our values. Similar findings have been reported by the German Federal Statistical Office in 2011 for 2009,[35] which correlate even better with our results.[34] Data for height, weight and BMI, obtained to assess the prevalence of obesity in Germany between 1985 and 2002,[36] in 1504 female volunteers (25–29 years) show that the subjects in our study are marginally taller, lighter and have a lower BMI.

In this context, however, it should be borne in mind that this study mainly involved students and university employees with the same lifestyle, with values slightly differing from the general population, and a likely over-representation of participants with a high social status.

Of the total participants in this study, 87.8% had a normal BMI, 22.3% more than Mensink et al[34] found for women aged 18–29 years. The relation of overweight with social status is well known; this confounder is also seen by the data from Mensink et al[34]; 36.9% of women with a low social status were overweight, 16.4% obese compared with 18.7% overweight and 4.4% obese women with a high social status. Helmert et al[36] calculated similar data using the equivalent household income; thus the different BMI values likely are explained by the participant selection preferentially from the students of the School of Dentistry in our university, with a high social status.

The back scan values indicate a characteristic posture of young females. Only small deviations from an ideal perpendicular position are noted; the ventral tilt of the trunk, the lateral deviation and rotation of the spine, shoulder and pelvis were very small. The posture is marginally scoliotic (the ventral trunk tilts marginally to the left side, the scapula is higher on the left side, the pelvis slightly elevated on the right side) with an expected rotatory component (a lumbar right tilt to compensate for the left-tilted ventral trunk, a slight twist of the processus spinosus to the right, the right scapula marginally more dorsal, the SIPS of the right iliac bone rotated anteriorly) (tab. 1). The spinal curve, defined by the thoracic and lumbar bending angle and the kyphosis and lordosis

angle, indicates that the angle in the thoracic spine area is marginally larger than that in the lumbar region (tab. 1), and a slightly kyphotic posture in the sagittal plane can be observed.

Handedness has no influence on these parameters which should be expected from the observed symmetry. However, since 95.3% of the participants were right-handed, no firm conclusions can be drawn for left-handed people. Also, whether an influence of the dominant leg[37] exists on the posture cannot be answered by our results. Appropriate test methods for the determination of these components should be used in further studies.

A gender comparison[27] shows only marginal differences in the upper body posture. Both studies used the same measurement system and data evaluation and thus allow a direct comparison of the values. Although the female upper body appears narrower and more delicate due to the weaker muscular shoulder girdle and the smaller chest, the ratio between chest and shoulder width is the same.[38]

The anatomical and constitutional differences are confirmed by the present data. In terms of the shoulder width, the fixed scapular landmarks indicate a larger distance of 2.9 cm in men than in women (table 1). In contrast, men have a smaller pelvis calculated from the SIPS markers (6 mm difference) which results in a wider shoulder than pelvis distance by 8.5 cm in men, but only 5.0 cm in women, confirming and quantifying the well-known gender-specific anatomical differences.

In addition to these constitutional differences, differences in the lordotic and kyphotic angles are calculated from the spinal column parameters. Thus, women have an average kyphotic angle of 52°, men of 46°; the lordosis angle is 46° for women and 31° for men. Thus, the spinal curvature in the thoracic and lumbar spine area is more pronounced in women than in men. The difference in the lordosis angle between the sexes is about 15° and in the case of the kyphotic angle with approximately 6°, however, men have an approximately 15° greater thoracic kyphosis angle than lumbar lordosis angle in contrast to a 6° difference of women. Consequently, the kyphosis angle is larger than the lordosis angle in both sexes, women are in a more balanced posture due to the smaller difference between the two angles.

Liu et al[39] tried to define standard parameters of cervical spine alignment and range of motion related to age, sex and cervical disc. These results underline the more pronounced thoracic kyphosis in women. The greater lumbar lordosis of the females can be traced back to sex differences in the pelvic shape: the wider pelvic blades of the female pelvis have a larger angle between the pubic branches, a larger transverse pelvic diameter and are lower. Thus, the pronounced female pelvic tilt leads to a larger lumbar lordosis. Consequently, a larger lumbar lordosis causes a thoracic hyperkyphosis. These (different) compensations are seen in the pelvic position in both sexes.[38] This position of the lumbar spine also affects the extent of the movement in the

flexion–extension testing of the trunk. The total task-specific hip motion ranges as measured from erect standing to the maximum flexion were higher in females than in males.[40]

Furthermore, the same authors report that female patients with chronic low back pain had higher regional hip and trunk motion ranges than male patients.[41] Why women have a larger lordosis angle currently is unknown. An extensive literature search in PubMED and other databases did not retrieve any published hypothesis. An explanation of physiological differences, however, has been forwarded to comparable sex differences in the pelvic anatomy for rodents and has been related to sexual behaviour in these animals. Guinea pigs show hormonally controlled, gender-related reproductive behaviour: male guinea pigs show a distinct sexual approach consisting of body raising, intromission and ejaculation, and female guinea pigs respond with a corresponding conceiving position of a predominantly lordotic lumbar posture.[42 43] At least for this species, the observed anatomical differences may translate directly into an apt reproductive behaviour. In both species, the pelvis itself has the same position in both sexes in a relaxed posture, and is positioned almost horizontally.

No similar explanation exists for differences in the shoulder region parameters either; the right shoulder is positioned more caudal in both sexes, but women have 'deeper' shoulders (increased scapular angle right/left).

All other positional parameters are nearly identical between men and women, with the differences being smaller than the margin of error, and likely have no clinical relevance.

The 3D back scan is a fast, non-contact method to quantify the body posture and is suitable for measuring body postures in both healthy persons and patients. It can quantify pathological positions like scoliosis, kyphosis, leg-length differences and functional movement disorders, as well as improvements by medical treatment. The chances and limitations of the measurement system and procedure[44–50] have already been discussed by Ohlendorf et al.[27 51] In the future, this method may allow to grade postural deviations, for example, by a grading system using the tolerance ranges for men and women, as has been done for bone densitometry in the t-scale and z-scale.[26]

CONCLUSION

Video raster stereography is a method to quantitatively measure the human 3D back surface. Healthy young women have an almost ideally balanced posture with minimal ventral body inclination and a marginal scoliotic deviation. In comparison with men, women have only small differences in upper body posture, with nearly identical normal values. These values allow a quantitative comparison with other studies for control and patient data, and may serve as an orientation in both clinical practice and scientific studies. Further studies could expand this method to age-related changes in body posture, quantitative assessments of postural changes in relevant diseases and improvements by therapeutic interventions.

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