Standard reference values of the upper body posture in healthy middle-aged female adults in Germany

Daniela Ohlendorf1, Polyna Sosnov1, Julia Keller1, Eileen M. Wanke2, Gerhard Oremek1, Hanns Ackermann2 & David A. Groneberg1

In order to classify and analyze the parameters of upper body posture, a baseline in form of standard values is demanded. To this date, standard values have only been published for healthy young women. Data for female adults between 51 and 60 years are lacking. 101 symptom-free female volunteers aged 51–60 (55.16 ± 2.89) years. The mean height of the volunteers was 1.66 ± 0.62 m, with a mean body weight of 69.3 ± 11.88 kg and an average BMI of 25.02 ± 4.55 kg/m². By means of video raster stereography, a 3D-scan of the upper back surface was measured in a habitual standing position. The confidence interval, tolerance range and ICCs were calculated for all parameters. The habitual standing position is almost symmetrical in the frontal plane the most prominent deviation being a slightly more ventral position of the left shoulder blade in comparison to the right. The upper body (spine position) is inclined ventrally with a minor tilt to the left. In the sagittal plane, the kyphosis angle of the thoracic spine is greater than the lordosis angle of the lumbar spine. The pelvis is virtually evenly balanced with deviations from an ideal position falling under the measurement error margin of 1 mm/1°. There were also BMI influenced postural variations in the sagittal plane and shoulder distance. The ICCs are calculated from three repeated measurements and all parameters can be classified as “almost perfect”. Deflections from an ideally symmetric spinal alignment in women aged 51–60 years are small-scaled, with a minimal frontal-left inclination and accentuated sigmoidal shape of the spine. Postural parameters presented in this survey allow for comparisons with other studies as well as the evaluation of clinical diagnostics and applications.

Abbreviations
TA Tolerance area
CI Confidence interval

With the widespread high standards of living, the impact of demographic change on societies has become increasingly noticeable1. The average age of populations and the percentage of older people is rising2, a high number of whom are healthy and require no assistance in their daily life which is reflected in the disability-free life expectancy3. Furthermore, an increasing number of people are working beyond their statutory retirement age4. Nevertheless, while changes in the body posture occur constantly with age, there is currently no adequate classification system for postural parameters. The quantity and quality of transformations need to be evaluated to differentiate the physiological from the pathological processes5. Additionally, standardized baselines enable the tracking of the temporal progress of ailments6 and therapeutic progress, providing a guideline for judging the necessity for therapy and evaluating its effectiveness7.

In many cases, measurements are taken after the reporting of symptoms as back pain, restriction of movement8 or visible asymmetries. Therefore, most of the available data regarding the upper body posture originates in medical diagnostics and, thus, deals with patients and a variety of illnesses9 or conditions after treatment10. Due to these circumstances, the timing of the diagnostics and intervention can occur after the optimum time. With

1Institute of Occupational Medicine, Social Medicine and Environmental Medicine, Goethe-University, Frankfurt/Main, Theodor-Stern-Kai 7, Building 9A, 60590 Frankfurt/Main, Germany. 2Institute of Biostatistics and Mathematical Modeling, Goethe-University, Frankfurt/Main, Theodor-Stern-Kai 7, Building 11A, 60596 Frankfurt/Main, Germany. *Email: ohlendorf@med.uni-frankfurt.de
appropriate essential criteria, not only can invasive interventions be avoided, but also risk assessments can be developed which allow the estimation of disease progression or stagnation. Prophylactic procedures, according to the individual risk, can be established which may influence the speed of progression. Consequently, keystones for health-associated parameters and quality indicators are needed, as, for example, falling is the most frequent cause of fractures and head injuries in older people, while there are indications of a link between the shift of the center of gravity and spinal imbalance.

Although the measured value of the parameter and its classification are important for diagnostics, the speed of temporal evolution can also be crucial in deciding the need for therapy. Most of the current literature which concerns the upper body posture in women deals with changes during or after pregnancy, following breast cancer treatment or with participants suffering from osteoporosis, back pain or other musculoskeletal or degenerative illnesses.

In order to interpret these measurements, references from healthy subjects are needed; these would provide a baseline for further studies and the evaluation of the current status in patients. Reference values can also increase the quality of medical diagnostics by aiding in the choice of the most appropriate therapy and the documentation of its course. It is, therefore, required that reliable and reproducible test procedures are established and that the data on standard values for upper body postures is accessible in order to investigate asymptomatic individuals. With this approach, combining screening tests and individual risk factor analysis together with the raising of awareness of spinal health, the sustainability and quality of medical treatments can be maintained, keeping a high quality of life in all age groups and avoiding the deterioration of posture. One method to visualize the upper body posture without X-ray procedures is video raster stereography.

Video raster stereography is a radiation-free and touch-free method to depict the back surface in three dimensions with a high (intra- and inter-day) reliability and reproducibility; with the use of given anatomical landmarks its accuracy increases. Furthermore, the brief procedure simplifies the survey and makes it more accessible for participants.

A methodology paper by Ohlendorf et al. described the project to measure the upper body posture in dependence of age and gender of the working population in Germany via video raster stereography. However, up to now, the only published standard values of the upper body posture describe females aged 21–30 years, males aged 18–35 years and 41–50 years.

Not only age that affects physical changes, but also gender. Gender, for example, has a different life expectancy and incidence of age-related diseases. With regard to this, women between the ages of 51–60 years are particularly interesting, as menopause usually begins in this age group. Those women experience a special, far-reaching change in weight after the completion of growth and hormonal changes during puberty. Hormonal changes during menopause can lead to postmenopausal osteoporosis which in turn affects the musculoskeletal system. The spine is often affected by kyphosis or load fractures of the vertebral bodies as a result of bone density loss. Since the menstrual cycle affects postural stability, e.g., through increased parasympathetic activity, its change during or absence after menopause can also affect posture. In addition, with increasing age, muscle mass and physical strength decrease with increasing age. Hormonal changes with increased androgen levels, e.g., testosterone, compared to estrogen levels, may contribute to increased total body fat mass but also to a shift in its distribution. There is also evidence for a link between hormonal balance, the reduction of leg fat and the accumulation of abdominal and visceral fat tissue. The menstrual cycle has an impact on postural stability, its change and absence during the menopause may also affect posture. Conclusively this situation demands an upper body posture classification with the previously addressed scopes of application.

The advantage in surveying a homogenous group lies in reducing the variance and increasing the informative value by minimizing effects of age and gender on postural characteristics. Thus, the aim of this study is defining these reference values with tolerance range and confidence intervals for healthy women aged 51–60 years. This can provide a baseline for categorization and comparison either for other studies or in clinical application.

**Material and methods**

**Subjects.** 101 physically healthy female volunteers in this study were recruited with ages ranging from 51 to 60 years (55.16 ± 2.89 years). The median height was 1.66 ± 0.62 m (lower tolerance 1.54 m and upper tolerance 1.78 m; lower confidence 1.65 m and upper confidence 1.68 m), the mean weight was 69.3 ± 11.88 kg (lower tolerance 45.02 kg and upper tolerance 93.57 kg; lower confidence 66.9 kg and upper confidence 71.69 kg) and the mean BMI was 25.02 ± 4.55 kg/m² (lower tolerance 15.91 kg/m² and upper tolerance 34.12 kg/m²; lower confidence 24.12 kg/m² and upper confidence 25.91 kg/m²).

According to the WHO classification, 3.96% were underweight, 52.48% had normal weight, 29.7% were pre-obese and 13.86% were obese. The volunteers were acquired through personal approach in dental offices in Frankfurt am Main (Germany) and Heidelberg (Germany), as well as at the “Carolinum” dental university hospital, Frankfurt am Main (Germany).

All subjects filled out the anamnesis questionnaire of the Centre for Dental, Oral and Maxillofacial Medicine of the Goethe University Frankfurt am Main. In addition to questions regarding TMD (temporomandibular joint dysfunctions) or problems with masticatory muscles, the health status, questions on general diseases such as osteoporosis or diabetes mellitus or weekly physical activity were also asked.

The frequency of their physical activity was surveyed: 76.24% exercised regularly, at least once weekly. Furthermore, the participants had a wide variety of employment, such as working in IT, nurses, teachers, housewives, working in retail or journalists.
All subjects were healthy and free of musculoskeletal complaints and, therefore, they were not being treated for any conditions. Using a questionnaire, disorders in the musculoskeletal or the temporomandibular system were excluded.

Exclusion criteria were: disorders of the musculoskeletal system which required medication, physiotherapy, osteopathic or orthopedic treatment, or were associated with restrictions of movement, e.g. osteoporosis or spinal disc prolapse. In addition, participants who had traumas or operations in the last two years were not included in the study.

A correlation coefficient of ≥ 0.25 (evaluation according to Evans) and a power of 80% showing at least a significant weak correlation can be assumed, hence a case number of n = 100 can be expected. All volunteers were healthy (none were patients who were undergoing medical treatment) and informed about the study design before giving written informed consent. The study was approved by the local medical ethics committee of the medical faculty (Goethe-University Frankfurt; No. 303/16) in accordance with the relevant guidelines and regulations and its later amendments (Declaration of Helsinki, 1964).

**Measurement system.** In order to determine the upper body posture a three dimensional back scan was conducted with the videorasterstereography back mapper “ABW-BodyMapper” (ABW GmbH, Frickenhausen, Germany) (Fig. 1). In the process a defined stripe pattern is projected onto the back surface which is then captured by a camera with a defined angle. The projection has a frequency of 50 Hz and a resolution of 1/100 mm. Through a triangulation technique, a 3D model of the back is obtained and parameters defining the spinal posture are calculated. The scan takes 15 recordings in approximately half a second. The system error is specified as < 1 mm (manufacturer information) and the reproducibility is limited by the calculations of the upper body posture defined by markers directly on the skin (< 0.5 mm). Yi et al. have calculated the intra- and inter-reliabilities of this measurement system and described it as good in both cases. Furthermore, they also proved the correlation between the Cobb angle via X-ray radiography and the bodymapper of the lordosis and kyphosis angles. They concluded that the accuracy of the data increases with the experience of the investigator who places the landmarks on the back of the subject to be measured. Therefore, an experienced or trained examiner was used for this study.

Twenty-three parameters could be evaluated, grouped into three sections:

The first group describes the shoulder area, the second outlines the spine while the third group characterizes the pelvis (Fig. 1). A detailed description of the parameters can be found in Ohlendorf et al.’s methods paper.

**Experimental setup.** Subjects were asked to undress their upper body down to their underwear, from the neck down to the lower spine; long hair was tied up and necklaces or other reflective jewelry was removed. In order to standardize the position, an orientation line was placed orthogonally to the scanner on the floor to align the big toes. Six reflective markers were then placed on the skin surface, according to the following defined skeletal structures: vertebra prominens C7, sacrum point at the beginning of the intergluteal cleft, angulus inferior
The measurements of the third group describe the pelvic region. The distance between the PSIS left and PSIS right was 92.23 mm (TA 66.02–118.43 mm; CI 89.64–94.81 mm), while the height difference between the PSIS left and PSIS right amounted to 0° (TA – 5.26° to 5.26°; CI – 0.42° to 0.30°). The torsion of the pelvis amounted to –0.72° (TA – 10.89° to 9.45°; CI – 1.73° to 0.28°) and the rotation of the pelvis to 0.77° (TA – 5.74° to 7.28°; CI 0.13°–1.42°).

Contrary to the shoulder inclination in the frontal plane, the pelvic measurements display an almost symmetrical, even position. According to the classification of Landis and Koch⁴⁸ all ICCs are to be classified as “almost perfect”, since the lowest ICC is found at the right scapula angle with an ICC of 0.814. All other ICCs have better values.

**BMI group comparison.** The BMI group comparison according to the WHO classification of the BMI was compared with the following groups: group 1 normal weight, group 2 pre-obese, group 3 obese and group 4 underweight.
| Parameter | Mean value/median | Lower tolerance | Upper tolerance | Lower confidence | Upper confidence | SD | 2SD | ICC |
|-----------|------------------|-----------------|-----------------|-----------------|-----------------|----|-----|-----|
| **Shoulder parameter** | | | | | | | | |
| Scapular distance (mm) | 164.06 | 120.94 | 207.17 | 159.80 | 168.31 | 21.56 | 43.11 | 0.935 |
| Scapular height (°) | 0.15 | −14.63 | 14.93 | −1.76 | 1.69 | 7.39 | 14.78 | 0.968 |
| Scapular rotation (°) | 1.40 | −4.96 | 7.77 | 0.78 | 2.03 | 3.18 | 6.36 | 0.972 |
| Left scapular angle (°) | 27.28 | 4.38 | 50.18 | 25.22 | 28.72 | 11.45 | 22.90 | 0.881 |
| Right scapular angle (°) | 28.53 | 12.87 | 44.19 | 27.19 | 29.86 | 7.83 | 15.66 | 0.814 |
| **Spine parameter** | | | | | | | | |
| Trunk length D (mm) | 452.32 | 404.20 | 500.44 | 447.57 | 457.07 | 24.06 | 48.12 | 0.993 |
| Trunk length S (mm) | 487.62 | 433.70 | 541.54 | 482.30 | 492.94 | 26.96 | 53.92 | 0.993 |
| Sagittal trunk decline (°) | −3.95 | −10.08 | 2.18 | −4.56 | −3.35 | 3.07 | 6.13 | 0.975 |
| Frontal trunk decline (°) | −0.31 | −2.98 | 2.36 | −0.57 | −0.05 | 1.33 | 2.67 | 0.949 |
| Axis decline (°) | −0.54 | −6.08 | 5.00 | −0.97 | −0.21 | 2.77 | 5.54 | 0.944 |
| Thoracic bending angle (°) | 14.51 | 6.29 | 22.72 | 13.69 | 15.32 | 4.11 | 8.22 | 0.953 |
| Standard deviation lateral deviation (°) | 3.63 | −0.33 | 7.59 | 3.06 | 3.89 | 1.98 | 3.96 | 0.897 |
| Standard deviation rotation (°) | 3.81 | −0.57 | 8.19 | 3.32 | 4.18 | 2.19 | 4.38 | 0.944 |
| Kyphosis angle (°) | 60.49 | 26.54 | 94.44 | 57.14 | 63.84 | 16.97 | 33.95 | 0.969 |
| Lordosis angle (°) | 52.61 | 20.09 | 85.12 | 49.40 | 55.82 | 16.26 | 32.51 | 0.972 |
| Lumbar bending angle (°) | 14.44 | 6.75 | 22.13 | 13.68 | 15.20 | 3.85 | 7.69 | 0.969 |
| **Pelvic parameter** | | | | | | | | |
| Pelvic distance (mm) | 92.23 | 66.02 | 118.43 | 89.64 | 94.81 | 13.10 | 26.20 | 0.972 |
| Pelvic height (°) | 0.00 | −5.26 | 5.26 | −0.42 | 0.30 | 2.63 | 5.26 | 0.945 |
| Pelvic torsion (°) | −0.72 | −10.89 | 9.45 | −1.73 | 0.28 | 5.09 | 10.17 | 0.897 |

Table 1. Upper body posture parameters including the mean or median values, tolerance range, confidence interval, standard deviation and 2 standard deviation. A description of the parameters can be found directly below each respective parameter. Normal distributed data are in italics. ICCs were classified as follows: 0–0.20 = “slight”, 0.21–0.40 = “fair”, 0.41–0.60 = “moderate”, 0.61–0.80 = “substantial”, 0.81–1.00 = ”(almost) perfect”. Data not normally distributed are printed in italics.
Significant group differences were found in the sagittal trunk decline ($p \leq 0.001$), scapula distance ($p \leq 0.01$), kyphosis and lordosis angle ($p \leq 0.001$ and 0.01, respectively) and lumbar flexion angle ($p \leq 0.001$).

The multiple pair comparison refers to the following group differences in the individual parameters:
- Sagittal trunk decline ($p \leq 0.02$) between groups 1 ($-2.89^\circ$) and 2 ($-5.27^\circ$) and groups 2 and 3 ($-5.90^\circ$).
- Shoulder blade distance: no significance.
- Kyphosis angle ($p \leq 0.001$) between group 1 ($55.07^\circ$) and 3 ($76.84^\circ$).
- Lordosis angle ($p \leq 0.01$) between group 1 ($48.70^\circ$) and 3 ($68.47^\circ$).
- Lumbar bending angle ($p \leq 0.02$ or 0.001) between groups 1 ($12.60^\circ$) and 2 ($15.21^\circ$), groups 1 and 3 ($17.72^\circ$) and groups 3 and 4 ($10.79^\circ$).

All significant pair comparisons are illustrated in Fig. 2.

Physical activity. Based on the information they provided in the questionnaire, the women were divided into four groups with regard to physical activity (1: no regular sport, 2: 1x/week, 3: 2x/week, 4: > 2x/week).

The group comparison does not show any significance ($p \geq 0.05$). The comparison of subjects who regularly exercise (groups 2, 3 and 4) is also not significant, as is the comparison of active subjects who exercise regularly ($n = 26$) and those who do not exercise regularly ($n = 75$) ($p \geq 0.05$).

Discussion

In this paper, standard values for the upper body posture are presented for healthy female subjects aged 51–60 years. Before discussing the reference values, it is useful to assess the anthropometric data. In comparison to the German Mikrozensus (the most important annual household survey of official statistics in Germany) from 2013\textsuperscript{49} and Mensink et al.\textsuperscript{50}, the participants in this study were near to the average for the female population\textsuperscript{45,49} especially in height (Table 2). The BMI in the study group was slightly lower than in the German population as there was a higher percentage of underweight and a lower fraction of obese women in the study group. This can be explained by the high percentage (76.26\%) of physical activity carried out by the present subjects; 31.68\% of the participants reported to exercise three or more times a week which indicates a high awareness of the importance of a healthy lifestyle and a high level of physical activity. Compared to younger women, aged 21–30 years old and also from Germany\textsuperscript{26}, the present subjects were smaller (about 3 cm), heavier (about 6 kg) and had a higher BMI (about 3.92 kg/m$^2$).

With regard to the reference values, it should first be noted that the women participating in this study have an almost ideally balanced, or rather symmetrical, upper body posture. Considering the sagittal plane, the posture is kyphotic on a small scale with the kyphosis angle being greater than the lordosis angle by 7.88\%. In detail, the participants’ upper body posture has a small rotational component, with the right shoulder having a higher position than the left while also standing more dorsally, but with the pelvic region being balanced; this
tions affecting the results.

As Gong et al. 39 used a broader age span of participants and, thus, fewer women in each age category (12 females aged 20–29 years, 12 aged 30–39 years, 8 aged 40–49 years, 12 aged 50–59 years, 20 aged 60–69 years, 26 aged 70–79 years and 12 aged 80–89 years), their study is more likely to be prone to inter-individual fluctua-
tions.

Changes in the lumbar lordosis were more heterogeneous, with ranges from no significant differences between younger and older people34 to a decreasing lumbar lordosis39.

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The upper body posture is also an important basis of assessment of life quality7. Many age related health problems are tightly interwoven with spinal changes as the shifting of the center of gravity32. These changes are often interconnected by compensatory mechanisms, thus the change in one parameter involves the adjustment of another46. With the participants of this study having, for example, a more pronounced spinal curvature than the younger group while also being healthy and physically active, the physiological changes of postural parameters with age and their respective classification would allow for assessment and risk analysis. As most professions have a sedentary component, the long-term effects of sitting on the parameters of the spine should be investigated.

Limitations of this study are potential causes of measurement errors and should be taken into consideration; for example lightening conditions, such as highlighted spots due to singular light rays or reflective hair accessories.

### Table 2. Comparison of anthropometric parameters between the present results and other studies.

| Age (years) | Present results | German average49 | Mensink et al. 50 | Ohlendorf et al. 60 |
|-------------|-----------------|------------------|------------------|-------------------|
| 21–30       | 51–60           | 51–60            | 51–60            | 21–30             |
| 30–39       | 166.00          | 165.50           | 163.10           | 169.00            |
| 40–49       | 69.30           | 70.05            | 70.90            | 60.30             |
| 50–59       | 25.02           | 25.55            | 27.40            | 21.10             |
| 60–69       | 3.96            | 2.00             | 1.00             | 6.00              |
| 70–79       | 5.48            | 5.55             | 8.10             | 87.80             |
| 80–89       | 29.70           | 31.30            | 33.50            | 4.70              |
| BMI > 30 (%)| 13.86           | 16.20            | 27.30            | 0.90              |
| BMI 18.5–24.9 (%)| 52.48 | 50.55 | 38.10 | 87.80 |
| BMI 25–29.9 (%)| 29.70 | 31.30 | 33.50 | 4.70 |
| BMI > 30 (%)| 13.86           | 16.20            | 27.30            | 0.90              |
| Height (cm) | 166.00          | 165.50           | 163.10           | 169.00            |
| Weight (kg) | 69.30           | 70.05            | 70.90            | 60.30             |
| BMI (kg/m²)| 25.02           | 25.55            | 27.40            | 21.10             |
| BMI < 18.5 (%)| 3.96 | 2.00 | 1.00 | 6.00 |
| BMI 18.5–24.9 (%)| 52.48 | 50.55 | 38.10 | 87.80 |
| BMI 25–29.9 (%)| 29.70 | 31.30 | 33.50 | 4.70 |
| BMI > 30 (%)| 13.86           | 16.20            | 27.30            | 0.90              |
(which should be removed before the scan) and extensive dark areas, such as large tattoos or shadows caused by excessive skin folds, can also affect the measurement process. In addition, the position of the BodyMapper in relation to the participant, or the placing of the reflective markers, can also influence the outcome. However, in this study, the placing was performed according to a standardized procedure by trained examiners. Under the premise of an experienced user of the BodyMapper, good inter-class correlations can be demonstrated (Table 1). Additionally, Yi et al. show appropriate intra- and inter-rater-reliabilities. Additional limitations of this study are described and discussed in the preliminary method paper.

Further investigations should expand these standard values with data regarding the various sex and age constellations to provide a solid baseline for scientific studies, clinical documentation and therapeutic application. Based on this broad database, it could also be investigated as to how the parameters change with age and sex. According to the influence of sedentary time, the proportion of working hours should be investigated further in order to evaluate its effects on posture and links to risk assessment associated with spinal parameters.

Conclusion

Overall, the women participating in this study have a balanced upper body posture with a slight tilt to the left in the shoulder and spinal column, as measured by the video raster stereography. Further studies could amend this data by using groups of other ages and genders to observe differences and parallels. Furthermore, the diagnostics of misalignments in upper body posture and therapeutic progress in the treatment of spinal conditions could be evaluated.

Data availability

All relevant data are in the manuscript.

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**Correspondence** and requests for materials should be addressed to D.O.

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