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New population based reference values for spinal mobility measures based on the NHANES 2009–10

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Abstract

Objective—To report population based percentile reference values for selected spinal mobility measures in a nationally representative sample of 5103 U.S. adults ages 20–69 years examined in the 2009–10 U.S. National Health and Nutrition Examination Survey (NHANES).

Methods—Occiput-to-Wall Distance (OWD), Thoracic Expansion (TE), and Anterior Lumbar Flexion (ALF – modified Schober test) were measured by trained examiners in a standardized fashion. TE was measured at the xyphosternal level while the lower reference point for ALF was a line marked at the level of the superior margin of the lateral iliac crests. We report reference values based on the 95th percentile of OWD and 5th percentile of TE and ALF measurements, as well as other summary statistics for these measures in the study population.

Results—An OWD of more than zero was present in 3.8 % of participants while 8.8% of participants had out of range values for TE based the commonly used threshold of 2.5 cm. The 95th percentile of OWD measurement was zero while the 5th percentile measurements for TE and ALF were 1.9 and 2 cm, respectively. The spinal measures were significantly associated with gender, age, ethnicity, height, and body mass index. Exclusion of individuals with severe obesity (BMI > 35) changed the proposed reference values for TE and ALF to 2.2 and 1.9 cm, respectively.

Conclusion—We verified the reference value of zero for OWD. Using the reported population based percentile values, new reference values for TE and the ALF can be derived.

Limitation of spinal movement is a feature of progressive ankylosing Spondylitis (AS). Its importance as a disease manifestation is underscored by its inclusion in the modified New York criteria which are the gold standard classification criteria for AS (1;2). Furthermore, spinal mobility measures are used to assess disease status and response to treatment in AS (3;4). Population based reference values for these spinal mobility measures can facilitate their utilization for clinical and research purposes.

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The Occiput-to-Wall Distance (OWD), Thoracic Expansion (TE), and Anterior Lumbar Flexion (ALF) tests are among the most commonly used spinal measures in AS and belong to the core outcome measures recommended by the Assessment of SpondyloArthritis (ASAS) International Society (3). The modified New York criteria specifically include limitations in TE and ALF relative to normal values for age and sex as criteria for classification of AS (2). Several different abnormal cut-off values and methods for these mobility measures have been proposed. A normal value of zero is generally accepted for OWD. A normal value of more than 2.5 cm for TE was proposed in the original New York Classification criteria (1). This threshold value was proposed based on measurements in unspecified samples of healthy volunteers. In a follow up study, Moll and Wright reported normal range for TE based on its distribution in a sample of 262 “normal” subjects consisting of students, hospital staff, and nursing home residents in Leeds, United Kingdom (5). The proposed threshold values ranged from 1.1 to 4 cm in the investigated age and gender strata although the number of subjects in each subgroup was small (ranging from 8 to 31). In these studies, TE was measured at the level of fourth intercostal space while a subsequent study suggested that TE measurements at the level of xiphoid notch are more reliable in AS patients (6). There are no reports of normal reference values for TE measurements conducted at the level of xiphoid notch. Schober originally proposed a 4 to 6 cm threshold value for the ALF based on normal reference values in an unspecified sample of healthy controls (7). Moll and Wright also reported normal ranges for a modified version of the Schober test (8) based on its distribution in 237 unaffected relatives of patients with psoriatic arthritis (9). In this study, threshold values ranging from 3.4 to 5.5 cm were reported for various age and gender strata although the number of subjects in each stratum was small with sample sizes in the strata ranging from 5 to 34.

Despite the wide-spread clinical use of spinal mobility measures, their normal reference values have not been reported in representative population based samples. The goal of the current study was to report population based percentile reference values for selected spinal mobility measures (OWD, TE, and ALF) in a nationally representative sample of U.S. adults ages 20–69 years based on the 2009–10 U.S. National Health and Nutrition Examination Survey (NHANES).

METHODS

NHANES Data

NHANES is a cross-sectional, nationally representative survey monitoring the health and nutritional status of the civilian, non-institutionalized US population conducted by the Center for Disease Control. Data were collected via household interviews and direct standardized physical examination. In 2009–10 NHANES, selected spinal mobility (OWD, TE, and ALF) measures were obtained on the full sample of male and female participants, ages 20–69 years by trained Health Technicians. Respondents were selected through a complex, multistage, probability study design that has been described elsewhere (10).

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Spinal mobility measures

The examiners (Health Technicians) were professional anthropometry technicians who completed a 2-day training program with survey staff and an expert anthropometrist prior to the initiation of the survey. The training included an overview of the component, using the NHANES III anthropometry video, and demonstrations conducted by the expert examiner with volunteer subjects. Gold standard validation of measurement accuracy was performed twice yearly during the 2009–10 data collection. The goal of these replicate exams was to compare the differences in measurement results obtained by the expert consultant to those obtained by the individual Health Technicians in order to ensure high levels of reliability and data quality throughout the two-year survey period. The inter-observer reliability for TE and ALF was assessed by intra-class correlation coefficient (ICC). The average ICCs for chest circumference measurements in inspiration and in expiration were 1 and 0.99, respectively; and the average ICC was 0.92 for the ALF measurement. The relative Technical Error of the Measurements (TEM) (11;12) were also calculated by dividing the TEM for a given measurement by the average of that measurement. The relative TEMs were also acceptable for these spinal measures (see supplemental Table 1). The Bland-Altman Plots (Supplemental Figures 1–3) also confirmed that there was no systematic effect of size of measurement on the difference between the measurement pairs. For the OWD where 96.2% of the sample had a value of zero, the ICC and TEM could not be reliably estimated. Here, there were no discordant pairs for inter-rater agreement (OWD=0 vs. OWD >0).

All measurements were performed only once but they were taken by 2 Health Technicians, one performed the measurement and the second one verified the accuracy of technique. Details of the measurement procedures are provided in the NHANES 2009–10 Anthropometry Examination Procedures Manual (13).

OWD was measured by having the examinee stand with the back against flat measurement surface keeping the posture as straight as possible with the heels, buttocks and shoulders touching the rear measurement surface. Subsequently, the examinee was asked to have his/her occiput touch the wall while looking forward (Frankfurt Plane). If the distance between the occiput and wall was not zero, the OWD was measured with a caliper to the nearest 0.1 cm.

TE was obtained based on the chest circumference measurements at the level of the xiphoid notch. Specifically, two chest circumference measurements were performed using a rigid metal measuring tape: The first after a maximum inhalation and a second at full exhalation. TE was calculated based on the difference between these two measurements. In 13.7% of participants (26.5% of women and 0.9% of men), the Health Technician was unable to obtain the chest circumference at this level. In such instances, the examiner obtained the measurement at the next lowest level on the chest where a circumference measurement was possible. The distance between this level and the level of the xiphoid notch was documented in these cases. One Health Technician obtained the primary measurement with the metal tape after ensuring that participants' arms were raised above the head and the breathing instructions were understood and practiced one time for maximum inhalation and exhalation. The second Health Technician ensured that the measuring tape was positioned correctly and properly aligned horizontal to the exam room floor and that this alignment was

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maintained at the same position on the chest as the participant went from full exhalation to full inhalation. In the current study, TE measurements in 25 examinees (all women) were excluded because they were performed more than 5 cm below the xiphoid notch level in order to avoid extreme heterogeneity in measurement methods.

ALF was performed as follows: Two horizontal marks were made on the lower spine. The first mark is placed midway along a line level with the superior margin of the lateral iliac crests while the examinee was standing upright with their arms crossed and hands on shoulders, then a second mark was placed 10 cm above it. To reduce spinal curvature, the participant was asked to stand up as straight as possible and take a deep breath while the recorder made the baseline and 10 cm indicator marks on the back. Subsequently, the participant was asked to bend over at the waist keeping the knees straight with the hands reaching for/ or touching the ankle area if possible. The distance between the two marks was measured again. ALF measurement was calculated based on the second measurement minus the initial 10 cm. In the 2009–10 NHANES, the starting point for ALF measurement was at the level of superior margin of the lateral iliac crests instead of a line across the Dimples of Venus as originally proposed (7). This modification was necessary because the Dimples of Venus could not be visualized in a large number of participants in the preparatory pilot studies. The midway along a line level with the superior margin of the lateral iliac crests corresponds to L4-L5 while the originally proposed starting point corresponds to L5-S1 level on imaging (7;8).

In this survey, 6684 persons aged 20–69 were screened for participation; 5,001 consented to spinal measures examination; OWD, TE, and ALF were performed in 4936, 4613, and 4663 persons, yielding response rates of 73.8%, 69%, and 69.8%, respectively. These response rates are considered adequate as the standard benchmark for sample size sufficient to minimize the possibility of selection bias is 70% in population surveys that use random sampling. Demographic data including age and self-reported race/ethnicity were obtained during the interview while anthropometric (height and weight) data were obtained during the examination, and body mass index (BMI) was calculated (kg/m^2). Severe obesity was defined as a BMI>35 kg/m^2 (14). Participant’s gender was observed by NHANES interviewers. Forced vital capacity (in liters) obtained as part of NHANES Spirometry examination (15) was used as a surrogate for lung volume. Additional information about 2009–10 NHANES has been provided in our previous publications (16;17).

Participants with self-reported AS (n=28) were excluded from the current study because our goal was to examine the distribution of spinal mobility measures in the unaffected population.

In a sensitivity analysis, we also examined whether presence of pain/stiffness at the site of measurement substantially changed the proposed reference values. In this analysis, 442 individuals with current neck pain/stiffness, 246 with current mid-back pain/stiffness, and 750 with current lower back pain/stiffness were excluded from the analysis of OWD, TE, and ALF, respectively.

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ALF follow-up study

In a follow-up study, we determined ALF in 55 consecutive patients with AS or axial spondyloarthritis according to the originally proposed method with the starting point at the level of Dimples of Venus (7) and the utilized approach in the Survey (i.e. starting point at the level of superior margin of the lateral iliac crests). All these patients were seen at the University of Texas-Houston Rheumatology Clinic and all measurements were performed by the same examiner (JDR). The goal of this follow-up study was to determine how often the originally proposed anatomic landmark (Dimples of Venus) was visible and to investigate the correlation between the measurements according to the original and modified methods.

Statistical analysis

Mobile Examination Center (MEC) sampling weights were employed to account for differential probabilities of selection within the complex NHANES sampling design as well as to obtain mean, standard errors (SE), and percentiles of the spinal measures. Sample weights account for unequal selection probabilities of subgroups and adjust for non-response and non-coverage. As shown in Figure 1, the distribution of OWD data were strongly skewed to the right while the distributions of TE and ALF data closely represented normal distributions. Therefore, no mean or SE was reported for OWD. For example, the weighted mean and SE of OWD measurements in the overall study population were 0.21 and 0.03, respectively which did not reflect the distribution of these measurements in a meaningful way (Figure 1).

The OWD data were dichotomized (normal versus abnormal) for the analysis of correlates. Weighted logistic (OWD)/ linear (TE and ALF) regression analyses were used to investigate the relationship of demographic variables and BMI with the spinal mobility measures. We first investigated the univariable relationship of independent variables with the spinal mobility measures. Next, all variables with $p < 0.15$ in the univariable model were considered for the multivariable. A forward hierarchical variable selection strategy was followed for building the multivariable model. Variables with a multivariable p- value <0.05 were included in the final model. Multi-collinearity, first order interaction terms between the independent variables were also investigated and, subgroup analyses were also performed when the interaction term was significant. Weighted 95th percentile for OWD and weighted 5th percentile for TE and ALF were considered as reference values as these percentiles represent “out-of-normal range” values in individuals without AS in a nationally representative sample of U.S. adults. In addition, weighted mean and other percentile values were reported. All statistical tests were two-sided and performed at 5% level of significance. The analyses were performed using SAS 9.3 (SAS Institute, Cary, North Carolina, USA) and STATA (StataCorp LP, College Station, TX, USA).

RESULTS

Occiput-to-Wall Distance

The distribution of OWD data were strongly right skewed demonstrated by the fact that the median and the interquartile range for OWD were 0 in the overall population and

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investigated subpopulations. Furthermore, only 3.8% of participants (n=188) had an OWD of more than zero. Supplemental Table 2 shows the univariable association of demographic variables (age, height, gender, ethnicity) and BMI with OWD. As shown in the Supplemental Table 3, higher BMI and older age were independently associated with an abnormal OWD in multivariable logistic regression analysis while height was not associated with OWD in the multivariable model. Furthermore, there was a significant interaction between ethnicity and gender. Only Hispanic men were more likely to have an abnormal OWD than white men while female participants had lower likelihood of having an abnormal OWD than their male counterparts across all ethnic groups.

Table 1 shows 95th percentile of OWD measurements in the general population. The 95th percentile of OWD was zero. Tables 2 and 3 show the reference values for OWD stratified according to age and ethnicity in men and women, respectively. Next, we excluded participants with severe obesity from our analysis (n=850), which did not change the 95th percentile measurement in the overall population (Table 1). As shown in Supplemental Tables 4 and 5, this also did not substantially change our threshold estimates for OWD in the investigated strata except for the 50–69 age group.

Thoracic Expansion

Based on the commonly used thresholds of 2.5 cm for this spinal measure (18), 8.8% of participants (n=402) had an out-of-range measurement. Supplemental Table 6 shows the univariable and multivariable associations of demographic factors and BMI with TE. Severe obesity, older age, height, gender, and ethnicity remained independent correlates of TE in the multivariable linear regression analysis (r-squared of the overall model = 0.15).

Next, we investigated the association of the lung volume (forced vital capacity) with TE in univariable and multivariable models. As shown in Supplemental Table 7, forced vital capacity was also associated with TE in the univariable ($p<0.001$) and multivariable models ($p<0.001$). Only Hispanic ethnicity, gender, age, severe obesity were associated with TE in the extended model that included forced vital capacity (overall r-squared=0.2) while non-Hispanic Black ethnicity and height were not significantly associated with TE after adjustment for lung volume.

Table 1 shows the summary statistics of TE measurements in the general population. The 5th percentile of TE was 1.9 cm. Tables 2 and 3 show the distribution of TE stratified according to age and ethnicity in men and women, respectively. Figure 2 shows the centile curves of TE measurements stratified by age in men and women. Exclusion of participants with severe obesity (n=774) resulted in an increased reference value of 2.2 cm (Table 1). As shown in Supplemental Tables 4 and 5, this exclusion also resulted in slightly higher TE reference values in the investigated strata.

In a sensitivity analysis, all individuals in whom the TE measurement could not be performed at the xiphoid notch were excluded (n=714), resulting in only minor changes in the reference values; the mean (SE) and reference value (SE) of TE increased to 4.9 (0.1) and 2 (0.1), respectively. The minor change in measurements is supported by the fact that

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the majority of measurements (54.4%) conducted below the xiphoid notch were done within 2 cm of this anatomic marker.

Anterior Lumbar Flexion

Supplemental Table 8 shows the univariable association of demographic factors and BMI with ALF. As shown in the Supplemental Table 9, severe obesity, higher stature, and younger age were associated with higher ALF in the multivariable model while there was a significant interaction between gender and ethnicity. This interaction indicated that white women had significantly lower ALF than white men while non-Hispanic black and Hispanic women had higher ALF compared to their male ethnic counter parts; black men and women had higher ALF than their white counter parts while only Hispanic women had higher ALF than white women (r-squared of the overall model=0.15).

Table 1 shows the summary statistics of ALF in the general population while the ALF measurements are stratified according to age and ethnicity in men and women in Tables 2 and 3. ALF 5th percentile measurement was 2 cm. Figure 3 shows the centile curves of TE measurements stratified by age in men and women. Similar to the overall population (Table 1), the stratified values did not change substantially after patients with severe obesity (n=787) were excluded (Supplemental Tables 4 and 5).

Exclusion of Individuals with Discomfort at the Site of Measurements

After exclusion of individuals with current pain/stiffness at the site of measurement, the reference values for OWD, TE, and ALF remained 0, 1.9, and 2 cm in the overall population, respectively. Similarly, the exclusion of these individuals either did not change the reference values at all or lead to minimal differences in the investigated population subgroups (data not shown).

Anterior Lumbar Flexion Follow-up Study

The Dimples of Venus could not be visualized in 39.2% (22/55) of examined patients with AS or axial spondyloarthritis in our clinic. Therefore, the two ALF measurement methods could only be compared in 34 patients. The mean (SE) of the ALF according to the method utilized in the Survey was 3.5 (0.4) while the mean (SE) was slightly higher at 4.1 (0.4) according to the original Schober method. Furthermore, the measurements according to the two methods correlated strongly with each other (r^2=0.9, $p<0.001$).

DISCUSSION

The current study is the first report of spinal mobility measures in a nationally representative sample. We were able to determine demographic variables that correlate with these measures and provide reliable reference values for them using the large-scale 2009–10 NHANES data set. This study establishes the normative reference values for spinal mobility measures in the US population.

In the present study, the immediately recognizable normal value of zero for OWD was also in agreement with the 95th percentile threshold value (exception: men in the 50–69 age

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group). The observed increase in OWD among older men might be secondary to increased prevalence of diffuse idiopathic skeletal hyperostosis or cervical spine spondylosis in this subpopulation although this needs to be verified in independent studies.

The previously suggested threshold value of 2.5 cm (1) for TE is too high based on our data. TE measurements were performed at the level of fourth inter-costal level in previous studies (1;5) whereas the TE was determined at the level of Xiphoid notch in the current study. The TE determination at the fourth intercostal level can be inaccurate in obese individuals or in women with large breasts. TE measurements at the level of Xiphoid notch have been shown to result in a higher inter-observer reliability among AS patients (6). Despite above mentioned modification, TE could not be measured at the level of Xiphoid notch in around one fourth of women in the current study. However, a sensitivity analysis after excluding all individuals with TE measurements below the Xiphoid notch did not result in substantially changed reference values because the majority of measurements in this group of patients were conducted within 2 cm of this anatomic marker.

The proposed reference value for ALF was also lower than previously proposed (7). Besides significant difference in study population, the utilized method in determination of ALF was different in the present study than originally proposed. The modification to the original method described by Schober (7) was introduced because Dimples of Venus was not visible in many individuals and could not serve as a reliable anatomic marker. Schober had already acknowledged that this anatomic marker was not visible in all individuals and had suggested in such cases going hand's breadth above the rear top of the gluteal cleft and drawing the demographic line for the first point of the measurement (7). In a follow up study, we observed that the modified method results on average in approximately 0.5cm lower measurements but highly correlates with the results obtained by the original method (r^2=90), supporting the validity of the modified method. Furthermore, the high inter-observer reliability values for the modified method used in this Survey indicate that this can be used as reliable and practical alternative to the original Schober method. Nevertheless, follow-up studies which correlate the spinal mobility measurements with the spinal movement on radiographs are needed to formally validate the proposed modification in measurement of ALF.

Besides the Original Schober method and the modified approach used in the present studies, two other modified methods have been proposed for ALF measurements. The ASAS group recommended marking an imaginary line connecting both posterior superior iliac spines (close to the dimples of Venus) for determining the starting point of ALF measurements (19). The feasibility of this modification for the 2009–10 NHANES was not examined because this recommendation was published in 2009 as the design phase of the Survey was concluded and the data collection had already started. Moreover, Moll and Wright (8;9), as well as the study defining the Bath AS Metrology Index (BASMI) (20;21) utilized another modified version of the Schober test that differs from the methods used in 2009–10 NHANES or recommended by the ASAS group (19). They utilized the following method: The first mark is placed at the lumbosacral junction at the level of a line joining the dimples of Venus. Further marks are placed 5 cm below and 10 cm above the lumbosacral junction. The patient is asked to bend forwards as far as possible and the distraction between these 2

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marks is recorded. The distance between the two marked points before forward bending is 15 cm while this distance is 10 cm in the methods used in 2009–10 NHANES and ASAS Handbook (19). Therefore, the ranges proposed in the Moll and Wright (9) and BASMI (20;21) studies are not applicable to ALF methods proposed by 2009–10 NHANES or ASAS Hand Book.

In the present study, gender, age, ethnicity, height and BMI were associated with the spinal mobility measures although only a moderate portion of variation in these measures could be explained by these variables (r-squared of multivariable models was 0.15). Other factors (e.g. genetics or exercise) not investigated in this study might also contribute to variability in spinal measures. Consistent with previously published data (5;9), we observed that age and gender are associated with the spinal measures. In general, the spinal mobility decreased with increasing age. We also observed that spinal mobility measures varied according to ethnicity. Therefore, we stratified our results by age, gender, ethnicity subgroups. The large sample size in the current study enabled us to report reliable threshold values for the majority of subgroups as demonstrated by the relatively small standard errors across most strata. We also reported reference values after excluding patients with severe obesity. The reference values for TE increased slightly while the other threshold values did not change substantially in this subgroup analysis.

In the extended multivariable model of TE correlates, Black ethnicity was not an independent correlate of TE after forced vital capacity was added to the model while Hispanic ethnicity remained significantly associated with lower TE measurements. This indicates the observed lower TE among Black examinees may have been mainly because of lower lung volumes in this ethnic group (22) while this observation in Hispanics is independent of lung volume and other demographic variables.

The association of gender with ALF varied in the investigated ethnic groups. White women had lower ALF than white men while Black and Hispanic women had higher ALF than their male ethnic counter parts. This finding can have several potential explanations such as difference in exercise habits or body habitus that can be explored in future studies.

Similar to previous studies (2;5;7;9;23), we propose reference values based on normative data in unaffected individuals rather than examining patients with AS. Development of threshold values in patient populations although desirable is complicated by the fact that changes in spinal mobility measures can be due to acute/chronic inflammation (disease activity) or spinal ankylosis (disease damage) (24). Therefore, thresholds for spinal mobility in AS cannot be solely developed based on the structural damage (spinal radiographs). A validated combined marker of the disease activity and damage in the respective anatomic area is necessary to develop thresholds for spinal mobility measures in AS patient population, which is currently not available.

The strengths of the current study are the careful sampling of the study population to be representative of the US general population, the rigorously standardized measurement of spinal measures, and its adequate response rate. The study has also some limitations. Spinal radiographs were not obtained in 2009–10 NHANES. Therefore, we cannot examine the accuracy of the spinal mobility measures based on imaging findings. Furthermore, we cannot report on distribution of other important spinal mobility measures such as lateral lumbar flexion or cervical rotation. Moreover, all measurements were performed only once on each subject while the most recent recommendation of the ASAS group is to perform each measurement twice and to report the better measurement (19). This limitation is partially alleviated by the fact that all subjects received detailed, standardized instructions and that the breathing instructions for TE were practiced by participants prior to the measurement.

In summary, the previously proposed threshold values for TE and ALF appear to be too high for the US population. This study reports population based reference values for the three commonly used spinal mobility measures based on NHANES 2009–10.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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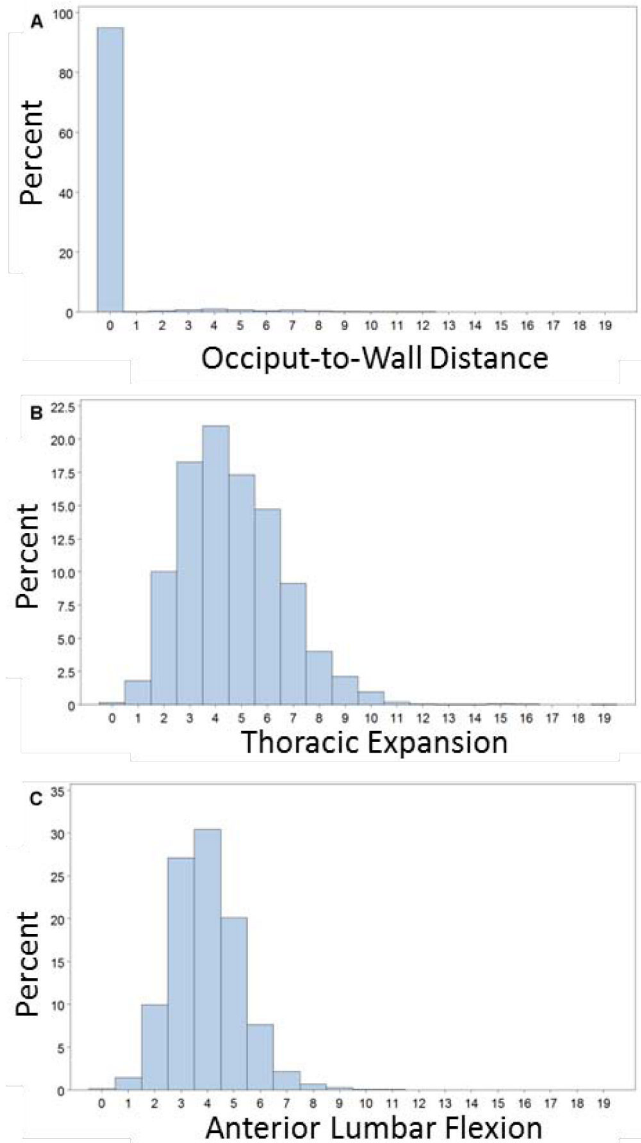

Figure 1.

Distribution of spinal mobility measures

A: Occiput-to-Wall Distance; B: Thoracic Expansion; C: Anterior Lumbar Flexion

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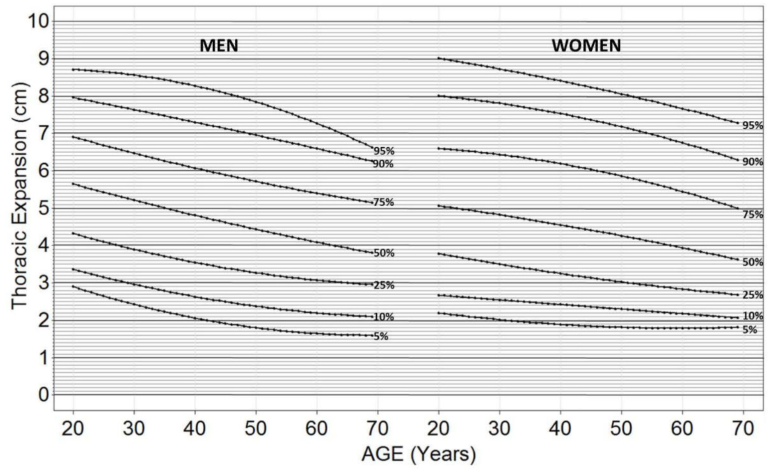

Figure 2.
Centile curves of Thoracic Expansion stratified by age in men and women

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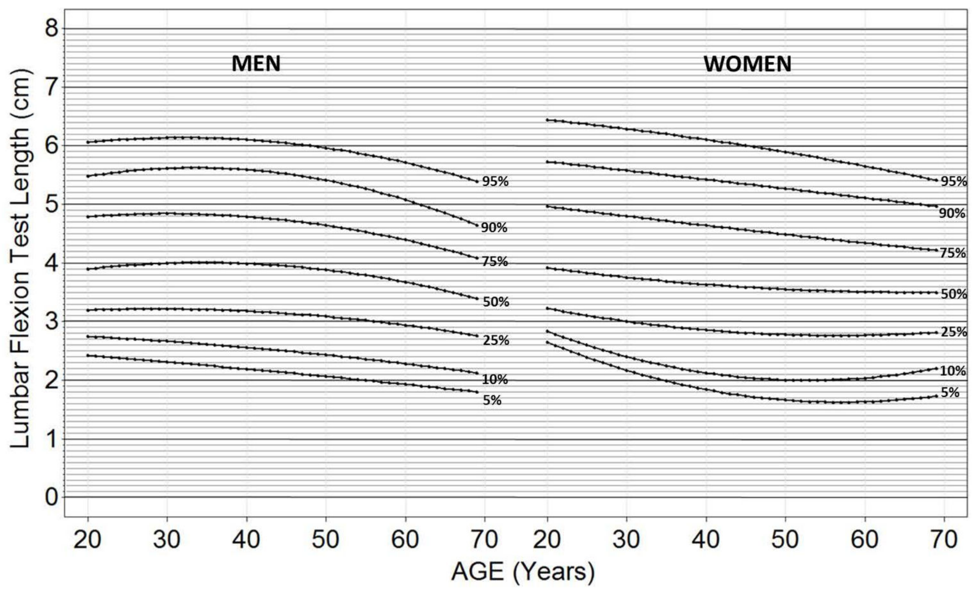

Figure 3.

Centile curves of Anterior Lumbar Flexion stratified by age in men and women

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Table 1

Summary statistics of spinal mobility measures in the overall population and after exclusion of participants with severe obesity

	Overall population			Participants without severe obesity		
	OWD	**TE**	**ALF**	**OWD**	**TE**	**ALF**
Mean (SE)	*	4.8 (0.05)	3.9 (0.03)	*	5 (0.05)	3.7 (0.03)
Reference value (SE)†	0	1.9 (0.07)	2 (0.04)	0	2.2 (0.08)	1.9 (0.04)

*Unable to report reliable mean and standard error of Occiput-to-Wall Distance because the data are strongly right skewed.

†95th percentile for the OWD and 5th percentile for TE and ALF.

Abbreviations: OWD: Occiput-to-Wall Distance; TE: Thoracic Expansion; ALF: Anterior Lumbar Flexion; SE: Standard Error

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Table 2

mmary statistics of spinal mobility measures stratified according to age and ethnicity in men

Category	Occiput –to-Wall		Thoracic Expansion		Anterior Lumbar Flexion	
	n	Reference value*†	n	Reference value* (SE)	n	Reference value* (SE)
All ethnicities						
20–35	744	0	713	2.5 (0.2)	712	2.3 (0.1)
36–49	695	0	662	2.1 (0.1)	665	2.2 (0.1)
50–69	936	7	885	1.6 (0.1)	878	1.9 (0.1)
Non-Hispanic white						
20–35	319	0	307	2.5 (0.3)	307	2.3 (0.1)
36–49	317	0	302	2.4 (0.2)	305	2.2 (0.1)
50–69	406	7.3	394	1.6 (0.3)	388	2.0 (0.2)
Non-Hispanic Black						
20–35	136	0	125	2.3 (0.3)	125	2.1 (0.2)
36–49	119	0	106	1.7‡	106	2.1 (0.2)
50–69	217	3.8	199	1.6 (0.1)	197	2.0 (0.1)
Hispanic						
20–35	241	0	234	2.4 (0.1)	233	2.2 (0.1)
36–49	216	0	214	1.6 (0.2)	214	2.1 (0.3)
50–69	276	6.0	261	1.5 (0.1)	262	1.8 (0.1)

*95th percentile for the Occiput-to-Wall Distance and 5th percentile for Thoracic Expansion and Anterior Lumbar Flexion.

†Unable to report reliable standard errors for Occiput-to-Wall Distance because the data are strongly right skewed.

‡Unable to calculate standard errors because there were not sufficient observations at the 5th percentile level of data distribution.

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Table 3

Summary statistics of spinal mobility measures stratified according to age in women

Category	Occiput –to-Wall		Thoracic Expansion		Anterior Lumbar Flexion	
	n	Reference value*†	n	Reference value* (SE)	n	Reference value* (SE)
All ethnicities						
20–35	851	0	759	2.1 (0.1)	799	2.2 (0.1)
36–49	794	0	726	1.7 (0.1)	751	1.7 (0.1)
50–69	890	0	808	1.8 (0.1)	834	1.7 (0.1)
Non-Hispanic white						
20–35	360	0	331	2.2 (0.3)	343	2.1 (0.1)
36–49	363	0	333	1.8 (0.2)	345	1.7 (0.1)
50–69	396	0	360	2.0 (0.1)	371	1.7 (0.2)
Non-Hispanic Black						
20–35	158	0	129	1.8 (0.4)	141	2.5 (0.4)
36–49	126	0	109	1.2‡	113	2.0‡
50–69	165	0	140	1.4 (0.2)	147	2.2‡
Hispanic						
20–35	273	0	242	1.8 (0.1)	257	2.4 (0.2)
36–49	248	0	236	1.9 (0.1)	240	2.0 (0.2)
50–69	287	3.3	270	1.4 (0.2)	276	1.5 (0.2)

* 95^{th} percentile for the Occiput-to-Wall Distance and 5^{th} percentile for Thoracic Expansion and Anterior Lumbar Flexion.

† Unable to report reliable standard errors for Occiput-to-Wall Distance because the data are strongly right skewed.

‡ Unable to calculate standard errors because there were not sufficient observations at the 5^{th} percentile level of data distribution.