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Original article

## Normative spino-pelvic sagittal alignment of Lebanese asymptomatic adults: Comparisons with different ethnicities

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### ABSTRACT

**Background:** Normative values of sagittal alignment are used as references for the diagnosis and treatment of spinal pathologies. There are currently no reference values for the normative sagittal alignment of Lebanese subjects. The objective is to describe normative values of full body sagittal alignment parameters in asymptomatic Lebanese adults and to compare the sagittal alignment of this population to that of populations of various origins.

**Methods:** Included subjects were aged 18 to 28 years old. Each subject underwent a full body biplanar X-ray exam with measurement of spine, pelvis and lower limb parameters of sagittal alignment. The sagittal alignment of the Lebanese population was compared to that of other ethnicities, previously reported in the literature, using one-way ANOVA.

**Results:** Ninety-two asymptomatic Lebanese young adult volunteers (48 males, 44 females, age =  $21.5 \pm 2.2$  years) were enrolled in this study. The mean curvature in the cervical spine was kyphotic ( $-4.3^\circ$ ) in women, while it was lordotic in men ( $5.4^\circ$ ). Men were found to be significantly more kyphotic than women ( $-58.3^\circ$  vs.  $-53.0^\circ$ ;  $p < 0.01$ ) but both sexes were found to have similar lordosis ( $61.6^\circ$ ) and pelvic incidence ( $52.0^\circ$ ). Lebanese subjects had intermediate pelvic incidence compared to other ethnicities but showed significantly higher thoracic kyphosis ( $p < 0.01$ ) and lumbar lordosis ( $p < 0.01$ ) compared to all other ethnicities.

**Conclusions:** This study established reference normative values for young adult Lebanese subjects. Most women were found to have kyphotic cervical spines. The sagittal alignment of Lebanese subjects differed significantly compared to that of other ethnicities.

**Level of evidence:** Level IV – cross sectional study.

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### 1. Introduction

The human spine is well understood when examined in the frontal plane. It is considered normal when straight and pathological when curved. Recently, there has been more focus on understanding the human spine when it is examined in the sagittal plane. Multiple authors have attempted to describe normative sagittal spino-pelvic alignment in order to establish references for diagnosing and treating spinal anomalies [1,2]. Furthermore, it has been long hypothesized that the sagittal spine differs sig-

nificantly between different ethnicities [3,4]. Authors have thus attempted to determine normative values of sagittal alignment parameters in Korean [5], Mexican [6], Chinese [7] and Japanese [8] populations. While some studies have been performed on the sagittal spines of subjects originating from Middle Eastern populations, none of them could be used to establish specific normative values of sagittal alignment since most of these studies included subjects with various pathologies of the spine [9–11], and all of them only studied the lumbar portion of the spine [9–13]. Our hypothesis was that Lebanese subjects had different sagittal alignment patterns compared to subjects of other ethnicities. The aim of this study was to describe normative values of full body sagittal alignment parameters in a young asymptomatic adult Lebanese population and to compare the sagittal alignment of this population to that of populations of various origins.

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## 2. Materials and methods

This is a cross-sectional IRB approved (USJ FM189) descriptive study of the sagittal alignment of asymptomatic Lebanese young adult volunteers. The inclusion criteria were age 18–28 years and no history of orthopedic surgery. Subjects were excluded if they presented any pain at the time of the study or if they had any musculoskeletal diseases (including Scheuermann's kyphosis, scoliosis or other spinal deformities). Most subjects were students recruited at our university. All subjects signed written informed consent.

### 2.1. Data acquisition

For each subject the following demographic characteristics were noted: age, sex, weight, height, and BMI. Each subject underwent a full body biplanar X-ray exam (EOS Imaging, Paris, France). All subjects filled out the SF-36 questionnaire in order to evaluate their health-related quality of life (HRQOL). All subjects were asked to stand upright in a relaxed manner with their shoulders flexed to about 45° and their hands placed on their zygomatic bones. This consensual free-standing position [14,15] was adopted in order to avoid the superimposition of subjects' arms over their spines on lateral radiographs (Fig. 1). Lateral radiographs were analyzed using Surgimap (Nemaris Inc., New York, NY) [16]. Spine, pelvis and lower limb sagittal parameters were calculated. These parameters are represented in Fig. 2. In particular, pelvic shift was defined as the linear horizontal distance between the S1 posterior superior corner plumb line and the anterior cortex of the distal tibia.

### 2.2. Statistical analysis

SF-36 data were adjusted [17] to previously published norms in the Lebanese population [18] and reported as means and standard deviations (SD) of the component scores. Sagittal spino-pelvic alignment parameters were compared between the two sexes using either Student's, Mann-Whitney's or Welch's unequal variance tests. A chain of correlations from head to feet was established in order to illustrate the relationships between sagittal alignment parameters using Pearson's correlation test.

Sagittal alignment of the Lebanese population was compared to that of other ethnicities, previously reported in the literature [2,5–8,19], using one-way analysis of variance (ANOVA). When the parameter was shown to be significantly different among ethnicities (ANOVA significant), Student's *t*-test was used to determine which ethnicity differed significantly from the Lebanese population. Significance level was set at 0.05. Statistical analysis was performed using IBM SPSS Statistics v.20.0 (IBM Corporation, New York, USA) and Epi Info v.7 (Centers for Disease Control and Prevention, Atlanta, USA).

## 3. Results

### 3.1. Subject demographics and health-related quality of life

Ninety-two asymptomatic Lebanese young adult volunteers were enrolled in this study. The demographics of the sample, along with between-sex comparisons, were reported in Table 1. The results of the SF-36 HRQOL questionnaire were reported in Fig. 3.

### 3.2. Full body analysis of sagittal alignment

Table 2 reports the sagittal alignment parameters of the whole sample along with the values of both the male and female groups. Lebanese women had a significantly larger (more anterior) pelvic shift and more knee extension compared to men. While PI and LL

were similar between males and females, the latter group had a significantly larger LL compared to their PI (i.e. PI-LL more negative). Women had significantly smaller maximal thoracic kyphosis compared to men. The cervical curvature significantly differed between the two sexes. The mean curvature in the cervical spine was kyphotic (−4.3°) in women, while it was lordotic in men (5.4°). Forty-six subjects (50%) presented cervical lordosis (C2/C7 > 0°) and 46 subjects (50%) presented cervical kyphosis (C2/C7 < 0°). While 29 of 44 women (66%) presented cervical kyphosis, 17 of 48 men (35%) presented with this same pattern. C2/C7 SVA was also significantly more posterior (24.7 mm) in women compared to men (31.2 mm). Furthermore, the thoraco-cervical mismatch (T1S minus C2/C7) was significantly larger in females. There were also differences in global sagittal alignment between the two sexes: women had a significantly more posterior T1SPi and C7/S1 SVA compared to men. The relationships between the sagittal parameters of the whole body are represented in Fig. 4. A chain of correlations linking the full body, from C2 to the feet, was established.

### 3.3. Ethnicity-related differences in sagittal alignment

Fig. 5 represents the sagittal spino-pelvic parameters of the Lebanese population alongside those of other ethnicities, with between-ethnicity comparisons. Table 3 reports the demographics of each of the ethnicities. The Lebanese population was found to have an intermediate pelvic incidence: with the older French ( $p = 0.04$ ) and Mexican ( $p < 0.01$ ) populations having a significantly larger pelvis and the Asian populations having a significantly narrower one ( $p < 0.01$ ) (Fig. 5).

The presently studied population also had significantly larger TK and LL ( $p < 0.01$ ) compared to all the other studied populations. Seeing as this population was significantly younger ( $p < 0.01$ ) than all of the other populations, it therefore had a relatively high SS and small PT compared to the results reported in the other studies. The Lebanese population had significantly higher SS compared to all the Asian populations ( $p < 0.01$ ) with similar PT, except for the Japanese population, which had significantly higher PT ( $p = 0.04$ ). The Lebanese population had similar SS compared to the French and Mexican populations but had significantly lower PT compared to the Mexican and older French populations ( $p < 0.01$ ).

## 4. Discussion

In this study, the sagittal radiological parameters of ninety-two young adult asymptomatic Lebanese subjects were reported and between-sex comparisons showed significant differences in the thoracic and cervical spines as well as in global sagittal alignment. A chain of correlations from head to feet illustrating the relationships between sagittal alignment parameters was established. This is the first study to report normative reference values on Lebanese subjects and to show that they differ from those of Caucasian, Asian and Central American populations.

### 4.1. SF-36 Health-related quality of life assessment

The assessment of health-related quality of life by the SF-36 questionnaire in this study showed that the included subjects had average scores above 50 for all components (Fig. 3). These results indicate that this sample of subjects had average or above-average HRQOL [17], thus confirming their asymptomatic status.

### 4.2. Full body analysis of sagittal alignment

Various significant differences were found in sagittal spino-pelvic alignment parameters between males and females (Table 2).

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