Discovering Skeletal Joe Median

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ABSTRACT

The purpose of this study is to produce an accurate anthropometric reference model, of the median human skeletal anatomy, for posture analysis using computer assisted design (CAD). Also, to determine if a single reference model can be proposed by combining data from existing studies of quantitative anatomy, including the cranium, spine, clavicle and pelvic girdle. A review of existing literature across the disciplines of anthropometrics, ergonomics, clinical anatomy, forensic science, and clinical biomechanics was carried out using books, academic journals, conference proceedings, international standards, government and military reports. Subject selection criteria included white males, from European, American, Middle Eastern, North African and South African sources. Only study samples with documented stature or other scalable references, between the ages of 19-65 years without spinal deformation or degradation were included. These findings were scaled to correspond to 2004 UK median stature data and combined as a process of normalisation. The measurements from existing studies have often been compared to each other, but as the studies have different stature averages, they are not numerically comparable. The current study is more holistic and accurate than existing studies with a resulting reference model, which includes 581 dimensions constructed to a precision of 0.1mm or 0.1° as full scale, 2D engineering drawings with accompanying spreadsheets of normalised dimensions. A resulting static 3D model was produced. This model is easily scaleable for changes identified in ergonomic secular trends. All newly scaled anatomical dimensions still remain closely comparable or confirm findings of other investigators. It was noted no guidelines for dimensioning anatomical data exists. Some recommendations are proposed. An anatomically accurate computer model has been generated which will aid further work in posture analysis.

KEY WORDS: Quantitative Anatomy, Anthropometrics, Median, Skeleton, Spine, Computer Assisted Design (CAD)

1. INTRODUCTION

Human beings are individually unique and static anthropometrics offer one method of quantifying distinction and mapping variation within a population. The average human has been explored by mathematicians [1], anatomists [2], artists [3,4], and within ergonomics [5,6,7,8]. Some discuss the idea of a quantifiable “optimal” or “ideal” profile or structure relating to form [9] or function [10]. The practice of using the average or median values in design specification is widely debated by investigators. Most of whom, when discussing the *“Fallacy of the Average Man”* [11], explain that to design to the median is a serious error. They discuss the limited possibility of an individual being average in stature, weight and chest circumference. Some suggest that being average across a number of body dimensions becomes less likely as more dimensions are included, but explain that the median is the *“most*

probable" member of the population and is most likely to have proportionate body dimensions [5]. In design practice it would be inconceivable to solve a problem from any single percentile or single guideline. However, defining some kind of reference is highly important. Galer states, *"For practical purposes in industry, measurement must be related to an "average man" and this has been agreed internationally"* [12]. The objective of this study was to produce a computer generated model of the median spine from the published literature of normal data.

2. METHODS

The investigation involved three stages including a review of existing literature, the normalization of these findings and documentation of results graphically and numerically.

2.1 Review of existing literature

Inclusion criteria defined the populations from which data was used, outlining the ethnic-geographic category of White males from American, European, Middle Eastern, North and South African sources, aged between 19 and 65 years, with known average stature. General body dimensions provided positional reference for more specific measurements from the cranium, pelvic girdle, clavicle and the spine. Similar female data was also included for the vertebrae as existing studies often included both genders and no significant difference was observed with individual bones. Studies using x-ray and magnetic resonance imaging (MRI) of participants in vivo and measurements of cadavers or x-ray imaging in vitro, were included. Exclusion criteria eliminated studies that focus on one figure type only, such as endomorphic, cadaver data that documents shrunken or diseased bones, and living samples with spinal degeneration, disease or trauma.

2.2 Normalization Process

Mean stature calculated from individual studies will yield different values because different samples of the population are used, making the data difficult to compare directly. Several researchers have compared their findings to others in this way [13,14,15,16,17,18,19,28], not including the effect of human scale. These studies document mean statures ranging from 1678mm to 1754mm. This 4.5% variation in height corresponds to a variation of approximately 25mm in vertical spine height. A proposed protocol [20] identifies this issue suggesting comparing intra-vertebral ratios rather than dimensions from different studies. Nevertheless, most existing literature record dimensions. Therefore a process of normalization by scaling was required. In ergonomics when combining data, stature is used for scaling [5,7]. In gait analysis both stature and leg length are used [21] and in forensic science spine lengths of partial corpses are used to predict stature [22]. The scaling protocol in this paper uses stature and affects linear measurements only. Angular data was applied directly. The ratio between the median UK stature for 2004 and the mean value of each original study was calculated. Studies that documented female vertebrae separately were scaled to correspond with the median male stature for reasons outlined in section 2.1. Once normalized, unique measurements were applied directly to the model, while identical measurements from different studies were averaged, to increase sample size (*n*). In some studies where data is limited but quantifiable results exist [13,23,30], normalization factors are estimated based on related vertebral geometry.

2.3 Applied outcomes

The normalized and pooled calculations were documented in spread sheets including standard deviations and the sample size for both the male and female. Computer models were produced for the male only. A 2D computer model was generated using Ashlar Vellum Graphite V7.1, an engineering drafting package, illustrating constructed geometry for the front (anterior) and side (sagittal) views of the normalized male median skeleton. Additional plan (transverse) view drawings were provided for the individual vertebrae. A frame of reference where the X-axis points forward, the Y-axis vertical, and the Z-axis pointing right, as suggested by the International Society of Biomechanics (ISB) [24] was used. All oblique dimensions were re-calculated using trigonometry to produce orthographic values indicative of elevation drawing. Anthropometrics literature and health surveys [2,5,7,25] informed the construction of general body regions. The C7 vertebrae and the Anterior Superior Illiac Spine (ASIS) positions provided primary datum locations for the spine and pelvis respectively. The spine's 'S' shaped profile was produced using Harrison's elliptical modeling for the cervical [27,28], thoracic [14] and lumbar [28] regions. Spine lengths and heights were calculated from data quantifying the vertebral geometry [13,16,17,18,23,27,28,29,31,32]. The S1 vertebrae location was identifiable along with the Hip Joint Centre (HJC) location [2,33] from which the remaining pelvic geometry could be constructed [34,35,36,37,38,39,40,41,42]. A 3D computer model was produced from these data using Discreet 3DS MAX V7.

3. RESULTS & DISCUSSION

"Skeletal Joe Median" has a stature of 1758.2mm for the male and 1623.1mm for the female. A total of 581 dimensions are applied in CAD. They include 42 for general anthropometrics, 61 pelvic measurements and 478 relating to the spine with 21 relating to its profile and orientation. More detailed anatomic measurements include 11 for the atlas, 27 for the axis, 23 for each of the remaining cervical vertebrae, 17 for each of the thoracic vertebrae and 20 for each of the lumbar vertebrae. Limited data was available for the thoracic spine. Assumptions were made for the angles of the spinous processes, by using uniformly increasing increments between the C07 and the L01 vertebrae. Figure 1 illustrates the sagittal view of the full-scale 2D engineering drawing. Construction accuracy is limited to 0.1mm or 0.1° reflecting the level of detail within existing literature.

To enable CAD reconstruction data must have clear positions of reference. Standards exist for measuring subjects for technological design (BS EN ISO 7250:1998) and the clothing industry (BS EN 13402-1:2001, BS 5511:1977) but no standards exist for the measurement of detailed anatomy. Furthermore, anatomical studies do not strictly follow standards for dimensioning methods. Graphical reconstruction can therefore be difficult as the relationship between measurements is unclear [16,17,18,23,30]. Occasionally oblique and orthographic measurements are combined together [34,37,43]. Several studies reference dimensions from multiple origins, which increases measurement error. This paper suggests that for future anatomical studies BS 308-2:1995 should be followed, with all values measured horizontally and vertically from a single datum point, when possible as standard protocol.

4. CONCLUSIONS

Although perhaps naturally unattainable, Skeletal Joe Median is the most probable member of the population, when assuming individual bones and their orientation as being separate traits. This paper proposes a quantifiable model with median physical characteristics and best theoretical posture absent of abnormalities, representing a structurally healthy sample group. To the best of the author's knowledge is the most holistic and precise proposal based on existing literature.

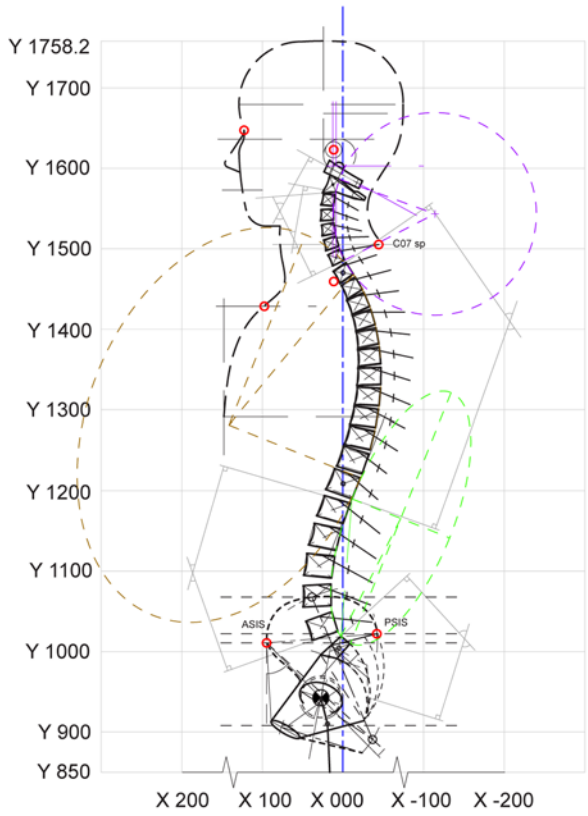

Fig. 1 Skeletal Joe Median Sagittal View

Fig. 2 Skeletal Joe Median 3D model

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