

**Measurement of the Positional Variability
of
Surface Anatomical Landmarks
over
Time**

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Abstract

Approach

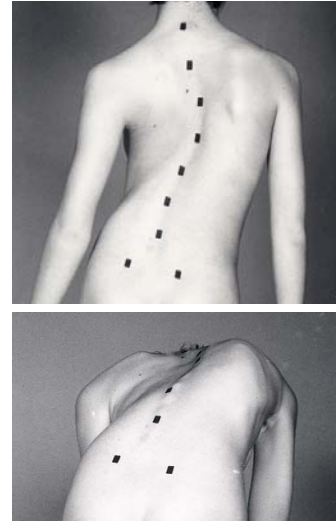
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For many patients, the motivation in seeking treatment is the improvement of their appearance rather than to correct an underlying skeletal deformity, so cosmetic concerns and the psychosocial impacts of scoliosis are important factors in the clinical decision-making process. There is new emphasis in the current evidence based medical environment on quantifying the components of back surface asymmetry with the objective of producing an agreed scoring to be used in developing treatment plans and assessing results. To date many techniques continue to rely on either a visual assessment or a single record of the relative positions of anatomical landmarks and back shape.

The aim of this study was to use multiple samples to establish the effects of posture, breathing and sway on the positions of anatomical landmarks and derived morphological measurements over time and to compare the specificity of single and averaged results when quantifying cosmetic defect.

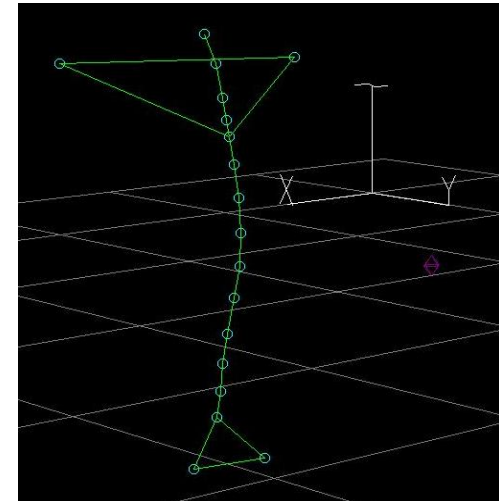
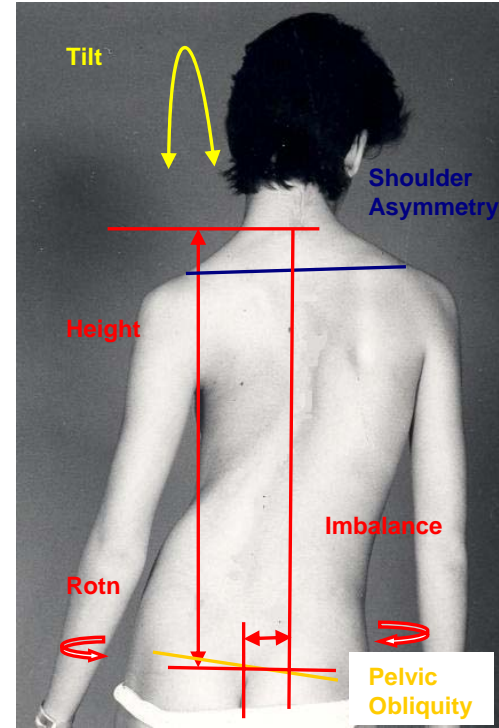


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Calculations of spine height, imbalance, tilt, pelvic obliquity, rotation and shoulder asymmetry were made from five sequential, 1,151 sample acquisitions of the tri-dimensional locations of landmarks captured from 30 adult subjects. The ranges, means and standard deviations (SD) were calculated for each of the measurements, for each subject acquisition. Measurement specificity was calculated as:

$$specificity = \frac{numberTrueNegatives}{numberTrueNegatives + numberFalsePositives}$$

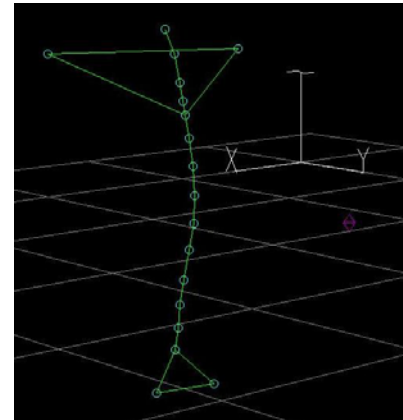
with a normality limit defined as $\pm 1SD$ calculated from the differences between all sequential acquisitions captured from all subjects. **True Negative** was defined as either each subject acquisition SD or range lying within the normality limit and similarly **False Positive** defined as lying outside this limit.



Equipment The study used an obsolete and modified 6 Camera, VICON motion capture system (Vicon Motion Systems Ltd., Oxford, U.K.) to acquire anatomical landmark positions (3 cameras) and surface data simultaneously at a rate of 60 frames/second. Anatomical locations were detected by cameras with synchronised strobe lights from spherical markers coated with a retroreflective material and placed by palpation. Only bright spherical images were sampled by each camera sensor, independent of the rate of subject movement and ignoring skin, fabric and other objects within the field of view.



The three dimensional locations of the markers were calculated using a photogrammetric reconstruction of multiple camera images. Accuracy of marker centre reconstruction in all axes was determined by experiment to be within a mean of 0.1mm, SD ± 0.2 mm, n = 4,500.



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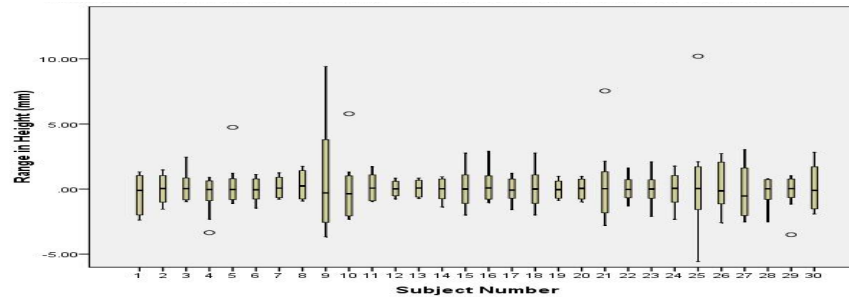
Participants The study group consisted of 30 skeletally mature adults (26 male, 4 female) exhibiting no systemic disease, significant chronic musculo-skeletal disorder or condition and had not been previously diagnosed with Adolescent Idiopathic Scoliosis. The age range was between 25 and 63 years, with an average age of 34.93 years (SD 7.71 years). Male participant ages averaged 34.35 years (SD 5.87 years) and females, 38.75 years (SD 16.29 years). The majority of subjects were right handed (26 of 30) with two subjects exhibiting leg length inequality, determined by measuring the relative heights of the popliteal fold behind the knees, of 10mm left and 19mm right respectively. All participant heights were between the 5th and 95th age/gender percentiles to remove any impact of outlying anthropometries on the results.

Protocol Each subjects was asked to stand naturally, arms slightly abducted in front of the apparatus for 5, 19.18 second sequential acquisitions resulting in 172,650 video frames of data available for statistical analysis.

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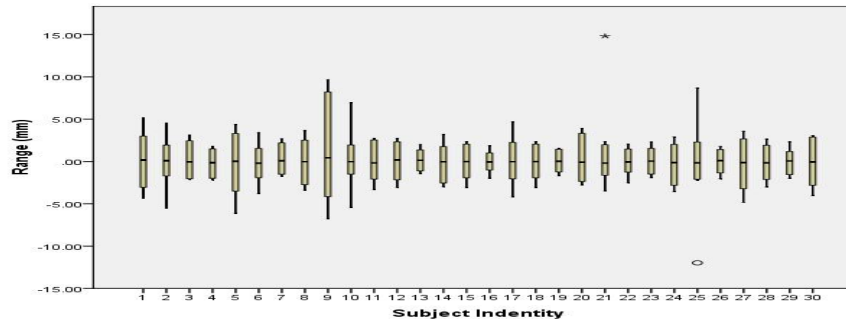
Spine Height - Specificity using averaged and single measurements The normality limit criteria (average Spine Height ± 1.62 mm) was applied to the standard deviations and range values calculated for each subject acquisition and the following results obtained:

$$\begin{aligned} \text{Specificity}_{\text{Averaged}} &= 145/150 = 96\% \\ \text{Specificity}_{\text{Single}} &= 244/300 = 81\% \end{aligned}$$



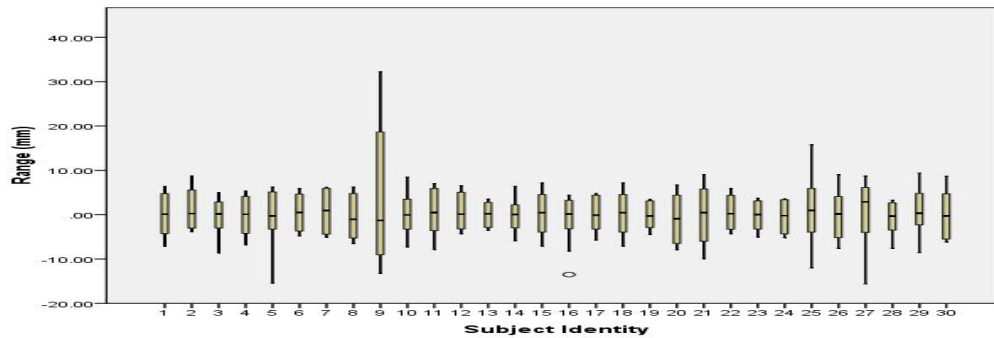
Imbalance - Specificity using averaged and single measurements The normality limit criteria (average Imbalance ± 2.50 mm) was applied to the standard deviations and range values calculated for each subject acquisition and the following results obtained:

$$\begin{aligned} \text{Specificity}_{\text{Averaged}} &= 146/150 = 97\% \\ \text{Specificity}_{\text{Single}} &= 219/300 = 73\% \end{aligned}$$



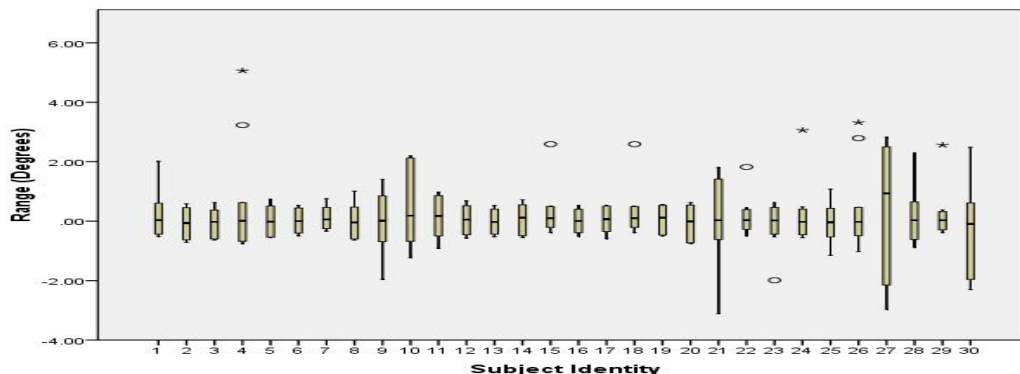
Tilt - Specificity using averaged and single measurements The normality limit criteria (average Tilt ± 4.84 mm) was applied to the standard deviations and range values calculated for each subject acquisition and the following results obtained:

$$\begin{aligned} \text{Specificity}_{\text{Averaged}} &= 145/150 = 97\% \\ \text{Specificity}_{\text{Single}} &= 202/300 = 67\% \end{aligned}$$



Pelvic Obliquity - Specificity using averaged and single measurements The normality limit criteria (average Pelvic Obliquity $\pm 0.22^\circ$) was applied to the standard deviations and range values calculated for each subject acquisition and the following results obtained:

$$\begin{aligned} \text{Specificity}_{\text{Averaged}} &= 121/150 = 81\% \\ \text{Specificity}_{\text{Single}} &= 8/300 = 3\% \end{aligned}$$

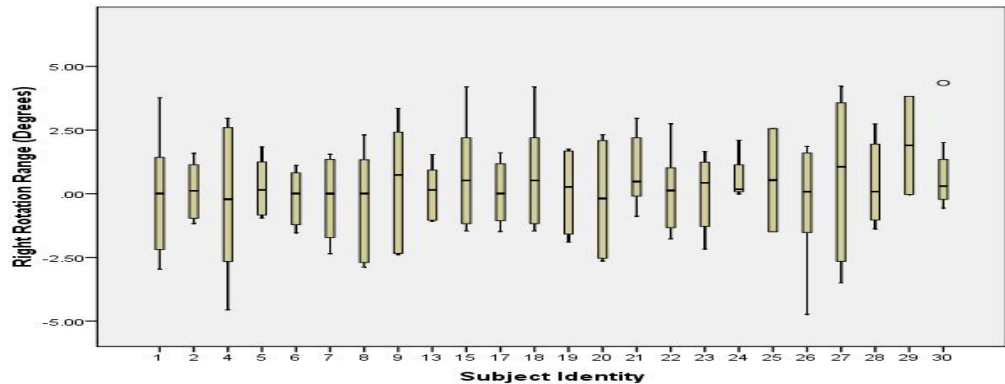
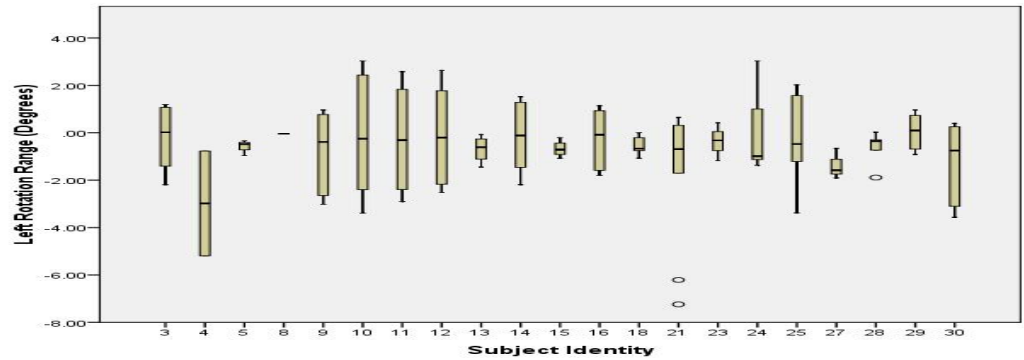


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Pelvic Rotation - Specificity using averaged and single measurements The normality limit criteria (average absolute Pelvic Rotation $\pm 0.79^\circ$) was applied to the standard deviations and range values calculated for each subject acquisition and the following results obtained:

Specificity_{Averaged} = 149/150 = 99%
 Specificity_{Single} = 73/300 = 24%

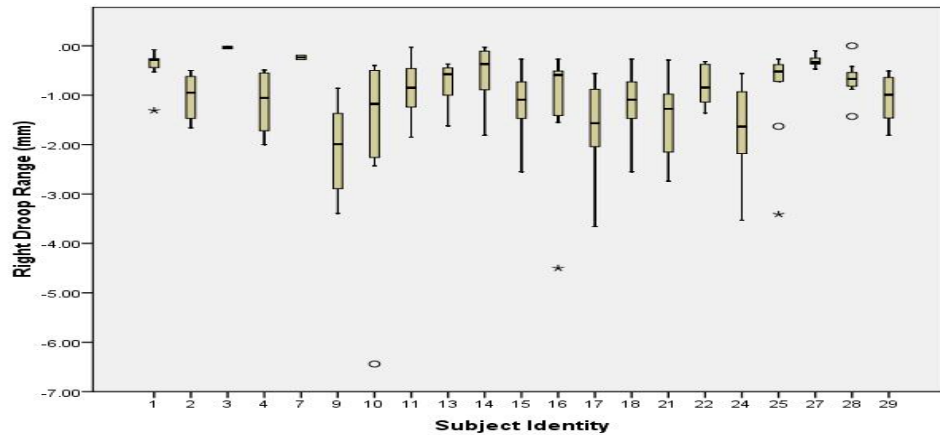
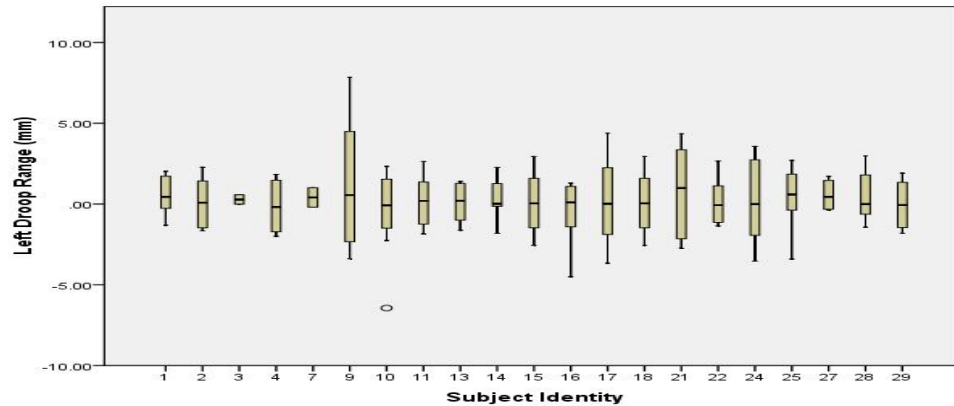


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Shoulder Droop – Specificity using averaged and single measurements The normality limit criteria (average absolute Shoulder Droop ± 2.02 mm) was applied to the standard deviations and range values calculated for each trial and the following results obtained:

Specificity_{Averaged} = 146/150 = 97%

Specificity_{Single} = 129/300 = 43%



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Discussion All spine height measurements must account for diurnal variations. Smith *et al.* [1] studied both erect and supine lumbar spines and confirmed earlier studies that gravitational forces on the erect spine leads to variations of an order of magnitude higher than the normality limit described in this study.

Conclusion The study has shown that there were significant improvement in the specificity for all morphological measurements when using averages rather than relying on a single sample.

The study has also established a normative baseline in a range of standard morphological measures acquired from skeletally mature subjects that may be useful when comparing results in future studies of pre and post operative AIS patients and their skeletally immature siblings.

Acknowledgement The advice and guidance given by Professor P.H.S. Torr, Professor in Computer Vision and Machine Learning is gratefully acknowledged.

1. Smith F.W. HY, Pope M.,Bashir W. MEASUREMENT OF DIURNAL VARIATION IN INTERVERTEBRAL DISC HEIGHT IN NORMAL INDIVIDUALS: A STUDY COMPARING SUPINE WITH ERECT MRI. *RADIOLOGICAL SOCIETY OF NORTH AMERICA: Scientific Papers Neuroradiology/Head and Neck (My Aching Back)*, 2003.