Spinal musculoskeletal dysfunction is a significant problem in Western society, with 70–85% of the general population experiencing one or more episodes of back problems during adult life and the annual prevalence ranging 15–45% (National Institute of Health Guide, 1997). In the UK, disability resulting from back pain has an annual cost to the NHS of an estimated £1.6 billion pounds (Klaber-Moffat et al, 1999; Somani, 2001).

Physiotherapy plays a key role in the management of back disorders, treating in excess of 1.3 million people each year in Britain (Foster et al, 1999). Causes of back dysfunction include poor sedentary habits, lack of postural awareness, postural abnormalities, spinal deformities, degenerative and systemic diseases and neurological diseases, among others (Maggee, 2002; Pengel et al, 2003).

Clinical assessment of spinal dysfunction involves the evaluation of back shape or symmetry. Variations in symmetry, shape or balance are generally believed (in conjunction with other symptoms) to be indicators or possible causes of dysfunction. With the onset of clinical governance, evidence-based practice has become paramount in all aspects of health. Numerous non-invasive objective methods varying in sophistication, cost and portability have been developed to measure and document back shape and posture.

The purpose of this current study was to assess the reliability of a new low-cost system on healthy young subjects. Intrarater reliability, using Pearson’s correlation and intraclass correlation coefficients of landmark points on 50 ‘normal’ subjects using a portable digital system, is reported. The results indicate that the system is reliable (P<0.001) and provides data suitable for evidence-based practice in clinical rehabilitation.

Key words: spinal dysfunction, evidence-based practice, clinical governance, postural assessment


Clinical assessment of spinal dysfunction involves the evaluation of back shape or symmetry. Variations in symmetry, shape or balance are generally believed (in conjunction with other symptoms) to be indicators or possible causes of dysfunction. With the onset of clinical governance, evidence-based practice has become paramount in all aspects of health. Numerous non-invasive objective methods varying in sophistication, cost and portability have been developed to measure and document back shape and posture.

The contour body tracer (Thulborne and Gillespie, 1976), spinal pantograph (Willner, 1981) and flexirule (Lovell et al, 1989) are the most com-
mon tactile methods reported. However, reports suggest that these methods are mainly used in research and rarely used in clinical practice (Kipling, 2001).

Hi-tech methods are costly because they are generally based on optical techniques requiring computer processing. Although highly accurate, they tend to be cumbersome to move and expensive to maintain. Moiré topography electronic measurement (Moreland et al, 1983; Tartaro and Austin, 1986), the Integrated Shape Imaging System (ISIS; Oxford Metrics Ltd, Oxford, UK) (Turner-Smith, 1988), rasterography (Hierholzer, 1999) and the Quan tec System (Quan tec Image Processing Ltd, Lancashire, UK) (Wojcik et al, 1994) are the most widely used systems. However, owing to their cost (more than £30,000, except for Moiré, which without electronics costs about £1000), requirement for experienced operator and complexity, the latter three systems are usually only accessible to specialist orthopaedic units, generally for the assessment of spinal deformities.

Further, slow uptake of these systems after initial excitement calls into question the clinical usefulness of the results as provided at the present time. Currently, objective measurement systems for postural evaluation are not widely available, especially in the NHS. Owing to financial constraints, many physiotherapy and orthopaedic clinicians who would benefit from such a system still have to rely on qualitative visual methods to assess posture and shape.

The Middlesbrough Integrated Digital Assessment System (MIDAS) is a new, low-cost (less than £5,000) portable and evidence-based system for the measurement of back shape and posture. The system, which has previously been described in a separate article (Warren et al, 2002), was found to be highly reliable (intrarater $r=0.99$, $p<0.0001$) on an anatomical mannequin. The purpose of this current study was to assess the reliability of the same system on healthy young subjects.

**SUBJECTS**

A convenience sample of 50 ‘healthy and asymptomatic’ physiotherapy students was used in this study. Their ages ranged 19–41 years (mean=22.9 years). There were 22 male and 28 female students with a mean body mass index (BMI) of 23 (ranging 16.9–30.3). Any subjects previously diagnosed with an associated orthopaedic problem were excluded from the study. Ethics approval was obtained from the local research ethics committee and informed consent was obtained prior to any measurements.

**INSTRUMENTATION**

The Microscribe 3DX Digitizer from Immersion Corp Ltd. (California) is a three-dimensional (3D) mechanical digitizer, developed for the computer graphics and engineering industries to create 3D computer models from physical clay, plastic or engineering parts. It is not dissimilar in its construction to a pantograph. It comprises an articulated, five-linkage, counterbalanced arm, which allows the stylus tip freedom of movement within a spherical volume of 0.63 m radius. Optical encoders in the joints record the joint rotations, allowing the measurement of joint angles from which the position of the stylus can be calculated (Figure 1).

The $x$, $y$ and $z$ coordinates (Figure 2) derived give the 3D location of the stylus tip relative to its initial position. In Figure 2, the frontal, sagittal and horizontal planes correspond to the $xy$, $yz$, $zx$ planes respectively. Mounting on a tripod enables it to be positioned correctly within its working range. Connected to a PC or laptop by a serial port, data can be collected and displayed from the digitizer.

**PROCEDURE**

Subjects were attired such that the whole of the back surface was visible. In total, 15 landmark points were palpated and marked with 8 mm diameter blue self-adhesive stickers on the subject’s back as shown in Figure 3, while in a standing position. The person then stood on a wooden platform in a relaxed position with his/her feet either side of a central block (20 cm wide), thus gaining standardization of foot position throughout the sample.

Previous work (Bettany and Harrison, 1992a) has shown that standardization of foot position can significantly improve scan reliability. Points were recorded by depressing a foot pedal when the stylus
tip was placed in contact with the marker. An audible signal was then produced and the coordinates were stored on computer disk. The subjects were allowed to relax for a minute and then recorded for a second time.

SELECTION OF ANATOMICAL LANDMARKS

The landmarks above were carefully chosen from current clinical methods, back shape studies and studies related to spinal deformities (Turner-Smith, 1988; Hierholzer, 1999; Leroux et al, 2000; O’Haire and Gibbons, 2000). The intention was to produce a contour tracing (map) for the cervical, thoracic and lumbar regions of the whole back (Figure 4, Table 1). The terminal vertebrae of the cervical, thoracic and lumbar curves were selected (C2, Vp, T12, Sa) as well as the apical vertebrae for each curve (Ca, Ta, La).

DATA ANALYSIS

Correlational analysis such as Pearson product-moment captures in a single index the association or relationship between two variables. It may be

<table>
<thead>
<tr>
<th>Table 1. Key to labelling of anatomical landmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Al</td>
</tr>
<tr>
<td>Ar</td>
</tr>
<tr>
<td>Sl</td>
</tr>
<tr>
<td>Sr</td>
</tr>
<tr>
<td>IC1</td>
</tr>
<tr>
<td>ICr</td>
</tr>
<tr>
<td>PS1</td>
</tr>
<tr>
<td>PSr</td>
</tr>
<tr>
<td>C2</td>
</tr>
<tr>
<td>Ca</td>
</tr>
<tr>
<td>Vp</td>
</tr>
<tr>
<td>Ta</td>
</tr>
<tr>
<td>T12</td>
</tr>
<tr>
<td>La</td>
</tr>
<tr>
<td>Sa</td>
</tr>
</tbody>
</table>
Clinical

helpful to think of correlation (or correspondence) in terms of interdependence of variables, so if one variable changes, the other one will too.

In this study, the association between repeated measures of x, y and z coordinates for all points were analysed using Pearson’s correlation coefficients (Batavia, 2001). Further, the intraclass correlation coefficient (ICC) was used to examine the agreement (or similarity) between pairs of scores, in addition to their correspondence. A significance level of 0.05 was used for statistical tests.

RESULTS

Association or correspondence

Pearson’s correlation coefficient analysis on the 15 points in the xy, yz and xz planes demonstrated a correlation coefficient value of between \( r = 0.92 \) and \( r = 0.99 \) (\( P < 0.0001 \)) for all points in all three planes (Table 2).

Agreement

ICC analysis on the 15 points in the xy, yz and xz planes demonstrated an ICC value of between \( r = 0.9187 \) and \( r = 0.9984 \) (\( P < 0.00001 \)) for all points in all three planes (Table 3).

DISCUSSION

Previous work by Warren et al (2002) on a mannequin demonstrated that the inherent accuracy of a contact mechanical system was extremely high (\( r = 0.999 \), \( P < 0.0001 \)) when using pre-palpated points. The current work confirms that the digitizer is also extremely accurate and reliable in the measurement of back standing posture in a sample of ‘normal’ subjects with a mean BMI of 23.

Intrarater correspondence as well as agreement measures were statistically significant (\( P < 0.001 \)) for all points in the frontal, horizontal and sagittal axes (xy, yz and xz planes). The accuracy of results are comparable to those reported from other high-tech systems (Turner Smith, 1988; Bettany et al, 1992b; Burwell et al, 1983; Wojcik et al, 1994; Hierholzer, 1999). Unfortunately, direct comparisons between these systems were not possible as different measures were used as a basis for calculating reliability.

Reliability and reproducibility are prerequisites for monitoring changes in back posture and efficacy of therapeutic interventions. The onset of evidence-based practice and clinical governance necessitates objective documentation of patient records to demonstrate effective assessment, treatment and management of patient care. However, further studies on different patient groups are required to provide further evidence of validity and sensitivity. The authors are hoping to complete this study in a more general population.

In addition, the uptake of any system in clinical practice requires a high level of acceptance among clinicians. This has been addressed in a previous study by van Schaik et al (2002), who studied the clinical acceptance of the digitizer for postural assessment as perceived by physiotherapists. Clinicians showed high levels of technology acceptance in terms of the three components perceived ease of use, perceived usefulness and intention to use.

The system should be particularly well suited to use in small clinical units, owing to its simplicity of operation, size and cost. The existing software allows calculation of height differences relative to fixed points on the spine. Future studies conducted by the authors will attempt to determine clinically relevant ‘normative’ values from the measured points. The intention will be to produce a topographical map of

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
<th>X axis</th>
<th>Y axis</th>
<th>Z axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-l</td>
<td>Left acromion process</td>
<td>( r = 0.927 )</td>
<td>( r = 0.943 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>A-r</td>
<td>Right acromion process</td>
<td>( r = 0.994 )</td>
<td>( r = 0.941 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>S-l</td>
<td>Left inferior angle of scapula</td>
<td>( r = 0.993 )</td>
<td>( r = 0.955 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>S-r</td>
<td>Right inferior angle of scapula</td>
<td>( r = 0.998 )</td>
<td>( r = 0.945 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>ICl</td>
<td>Left iliac crest</td>
<td>( r = 0.988 )</td>
<td>( r = 0.947 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>ICr</td>
<td>Right iliac crest</td>
<td>( r = 0.981 )</td>
<td>( r = 0.939 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>PSl</td>
<td>Left posterior superior iliac spine</td>
<td>( r = 0.985 )</td>
<td>( r = 0.942 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>PSl</td>
<td>Right posterior superior iliac spine</td>
<td>( r = 0.968 )</td>
<td>( r = 0.931 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>C2</td>
<td>2nd cervical vertebrae</td>
<td>( r = 0.957 )</td>
<td>( r = 0.949 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>CA</td>
<td>4th cervical vertebrae</td>
<td>( r = 0.960 )</td>
<td>( r = 0.937 )</td>
<td>( r = 0.999 )</td>
</tr>
<tr>
<td>VP</td>
<td>7th cervical/1st thoracic</td>
<td>( r = 0.940 )</td>
<td>( r = 0.951 )</td>
<td>( r = 0.999 )</td>
</tr>
<tr>
<td>TA</td>
<td>Apical thoracic vertebrae</td>
<td>( r = 0.956 )</td>
<td>( r = 0.909 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>T12</td>
<td>12th thoracic vertebrae</td>
<td>( r = 0.964 )</td>
<td>( r = 0.955 )</td>
<td>( r = 0.999 )</td>
</tr>
<tr>
<td>La</td>
<td>Lumbar apical vertebrae</td>
<td>( r = 0.958 )</td>
<td>( r = 0.952 )</td>
<td>( r = 0.998 )</td>
</tr>
<tr>
<td>SA</td>
<td>Sacrum point</td>
<td>( r = 0.946 )</td>
<td>( r = 0.954 )</td>
<td>( r = 0.996 )</td>
</tr>
</tbody>
</table>
standing back posture. This work is necessary for implementation of the system in clinical practice.

Known limitations, which the authors intend to quantify, are marking inconsistencies between different markers owing to palpation and the time gap between successive measurements. However, the former was not a cause of inconsistencies in the current study because marking was done only once for each subject by the same marker. In order to fully test consistency, the marking would have to be done by different markers and the measurements separated by a week or more.

The landmark points shown in Figure 4 form the basis for measurements of the back shape and hence the underlying spinal deformity. Since they are measured in three dimensions, they show not only the asymmetry and curvature in the frontal plane, but also the corresponding changes in the sagittal plane and the horizontal.

CONCLUSIONS

Initial results indicate the system to be a very reliable and accurate method of recording the 3D position of landmark points on the back and a promising technique for capturing back shape. The proposed system is portable and of low cost, and initial results suggest that it may be useful in a number of clinical settings – for example, physiotherapy and orthopaedic medicine, as well as spinal units.

Use of this system as an adjunct to traditional methods may also increase the effectiveness of postural management (Farley et al, 2000). The next phase of the research is to assess the system’s interrater reliability on healthy asymptomatics and patients with postural dysfunction and spinal deformities. Further research will investigate the presence of different back profiles and possible spinal indicators for back dysfunction. Spinal deformity requires the measurement of more points on the spine. Further research is required to establish the effect of different persons palpating and marking on outcomes.

Conflict of interest: none.


KEY POINTS

- The Middlesbrough Integrated Digital Assessment System has a very high intrarater reliability (P<0.001).
- The system has relatively low cost and high portability compared to other high-tech systems.
- It has a high clinical acceptance in terms of ease of use, usefulness and intention to use.
- It can be applied to a range of clinical areas.
Clinical

There has been a plethora of studies describing methodologies for back surface measurement (Alberti et al, 1992). Methods for optical measurement that have been developed and reported include stereophotography, Moiré topography and raster stereography. Optical scanning methods are also used, which provide spatial information relating to the 3D shape of the back.

While most non-contact systems are expensive, this study describes a simple, inexpensive method for spine and back assessment. The reported investigation is a continuation of a previous study from the same authors (Warren et al, 2002), which used a tactile 3D digitizer on a mannequin. This digitizer demonstrated high measurement accuracy when using predetermined anatomical points.

The reported technique promises to be an inexpensive methodology for back assessment, which has a potential for further development. Although the difficulties for novice operators who are unfamiliar with palpating and locating the spinous processes should be considered, this difficulty could be overcome by limiting the number of markers placed on the subject. This could be the natural progression for this study.

The reported technique promises to be an inexpensive methodology for back assessment, which has a potential for further development. Although the difficulties for novice operators who are unfamiliar with palpating and locating the spinous processes should be considered, this difficulty could be overcome by limiting the number of markers placed on the subject. This could be the natural progression for this study.

The reported technique promises to be an inexpensive methodology for back assessment, which has a potential for further development. Although the difficulties for novice operators who are unfamiliar with palpating and locating the spinous processes should be considered, this difficulty could be overcome by limiting the number of markers placed on the subject. This could be the natural progression for this study.

The reported technique promises to be an inexpensive methodology for back assessment, which has a potential for further development. Although the difficulties for novice operators who are unfamiliar with palpating and locating the spinous processes should be considered, this difficulty could be overcome by limiting the number of markers placed on the subject. This could be the natural progression for this study.