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Technical note

A quantitative measurement method for comparison of seated postures

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ABSTRACT

This technical note proposes a method to measure and compare seated postures. The three-dimensional locations of palpable anatomical landmarks corresponding to the anterior superior iliac spines, clavicular notch, head, shoulders and knees are measured in terms of *x*, *y* and *z* co-ordinates in the reference system of the measuring apparatus. These co-ordinates are then transformed onto a body-based axis system which allows comparison within-subject. The method was tested on eleven unimpaired adult participants and the resulting data used to calculate a Least Significant Difference (LSD) for the measure, which is used to determine whether two postures are significantly different from one another.

The method was found to be sensitive to the four following standardised static postural perturbations: posterior pelvic tilt, pelvic obliquity, pelvic rotation, and abduction of the thighs. The resulting data could be used as an outcome measure for the postural alignment aspect of seating interventions in wheelchairs.

1. Introduction

Supportive seating in wheelchairs is an established intervention for wheelchair occupants requiring assistance with postural control. Depending on the individual's rehabilitation goals, a seating system may aim to restore a balanced symmetrical posture, for example, to prevent the development or progression of deformity [1]. In other cases a seating system may aim to accommodate and support a posture which deviates from the symmetrical ideal. This type of accommodative/custom contoured seating may be provided, for example, for individuals with established contracture and/or deformity [2]. Accommodative seating may have numerous rehabilitation goals including providing optimal functional postural alignment within the individual's range of movement; managing pain and comfort; preventing further musculoskeletal deformation; and increasing the load bearing area, which it achieves through close correspondence of body shape and seat shape, leading to improved pressure distribution which is critically important for the prevention of pressure sores.

As with all medical and rehabilitation interventions, clinicians involved with the provision of a supportive wheelchair seating system seek to evaluate its effectiveness. Ideally such evaluation is conducted using a validated outcome measure and in the case of wheelchair seating, outcome measurement may focus on any of a variety of different aspects. These may include whether the postural aims of the system have been achieved, such as in the postural alignment section of the Seated Postural Control Measure (SPCM) [3] which examines the deviation of body segments from normal alignment, which is defined in the paper as "erect head and trunk with hip, knee and ankle joints at right angles". Alternatively they may examine whether physiological function has been improved, such as pulmonary function [4], or whether functional activity has been enhanced such as eating and drinking [5] or bimanual play [6]. In practice of course, pain and discomfort as reported or indicated by the wheelchair occupant is also frequently considered by clinicians in the evaluation of a seating intervention.

The development of a quantitative outcome measure for the postural aspect of supportive seating is however faced with two main challenges. Firstly, instrumented measurement of standard postural parameters, such as joint angles and body segment orientations, is practically difficult in many types of seat, because the seat itself obscures access for anatomical landmark palpation and goniometry etc. Secondly, for individuals with musculoskeletal deformity, seating must sometimes accommodate the occupant in an asymmetrical and unbalanced posture. This means that the desired goal cannot be described in terms of a single set of optimum parameters.

This technical note therefore proposes a measurement technique which aims to circumvent this problem by focussing on a constellation of accessible anatomical landmarks.

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The positions of these landmarks for different postures can be compared within-subject to establish how well the postural goal for a given individual has been achieved. It is hoped that this technique is quick and easy enough to be used in the clinical setting, and hence may be used as an outcome measure for the postural aspects of a supportive seating system.

2. Method

The principle underlying this method is the comparison of postures within the same individual. It is envisaged that the method may be used as an outcome measure for postural seating intervention by taking measurements on the wheelchair occupant at three stages during the provision of seating intervention. These stages are: before intervention, e.g. in the wheelchair occupant's original seat; during clinical assessment, when the desired posture is established and simulated with manual support; and after intervention in the newly provided seating system. The method will quantify the difference between pairs of postures to determine whether the seating intervention achieves a posture closer to the desired posture than the original seat.

Each posture is described in terms of the location in 3-dimensions of the following 8 anatomical landmarks which are easily accessible for palpation when seated: left and right anterior superior iliac spine (ASIS), clavicular notch, left and right shoulder (middle of acromiohumeral space), head (midpoint of glabella), left and right knees (midpoints of patellae) (Fig. 1). The position of each landmark is measured in 3-dimensional space using any appropriate technology, which in our testing was the MicroScribe G2LX (Immersion Corp., San Jose, CA) articulated arm co-ordinate measuring machine. Measurements will be referenced to the measuring device's defined origin and axis system. In the case of the MicroScribe the position and orientation of this axis system is determined from a calibration procedure which must be carried out before every measurement session.

A body-based orthogonal axis system is then derived from the resulting array of points. This is defined such that the *y*-axis corresponds to the line through the two ASISs with the positive direction being from right to left. The origin is defined as the midpoint of the ASISs, and the *z*-axis is defined such that it passes through the origin in the plane of the *y*-axis and the clavicular notch. The positive direction for the *z*-axis is inferior to superior. The *x*-axis can then be computed from the cross product of the *y*- and *z*-axes. The resulting axis system is described in terms of a 3×3 matrix containing the direction cosines of the body-based axes in the reference system of the measuring device.

To facilitate direct comparison of postures, each body-based axis system must be aligned. This is done by rotating and translating the points such that this body-based axis system aligns with the axis system of the measuring device. This means that the *x*, *y*, *z* co-ordinates of the anatomical points will then always be consistently oriented such that the ASIS points are located on the *y*-axis, equidistantly from the origin, and the *z*-axis falls in the plane of the *y*-axis and the point representing the clavicular notch. Once transformed into this reference system, ASIS co-ordinates will always take the form $(0, -y, 0)$ and $(0, y, 0)$ and the clavicular notch co-ordinate will always take the form $(0, y, z)$. The transformation is achieved by a sequence of 3 rotations about each axis and in our testing the order was firstly around the *z*-axis, then the *x*-axis and finally the *y*-axis. In practice however, any order may be used. The required angles to effect this rotation are found from Eqs. 1–3 (adapted from Kadaba et al. 1990 [7]) where r_x is the angle of rotation about the *x*-axis, r_y is about the *y*, and r_z about the *z*. y_x and y_z are the direction cosines of the body-based *y*-axis in the *x* and *z* directions of the reference system respectively, and x_z is the direction cosine of the body-based *x*-axis in the reference system *z* directions.

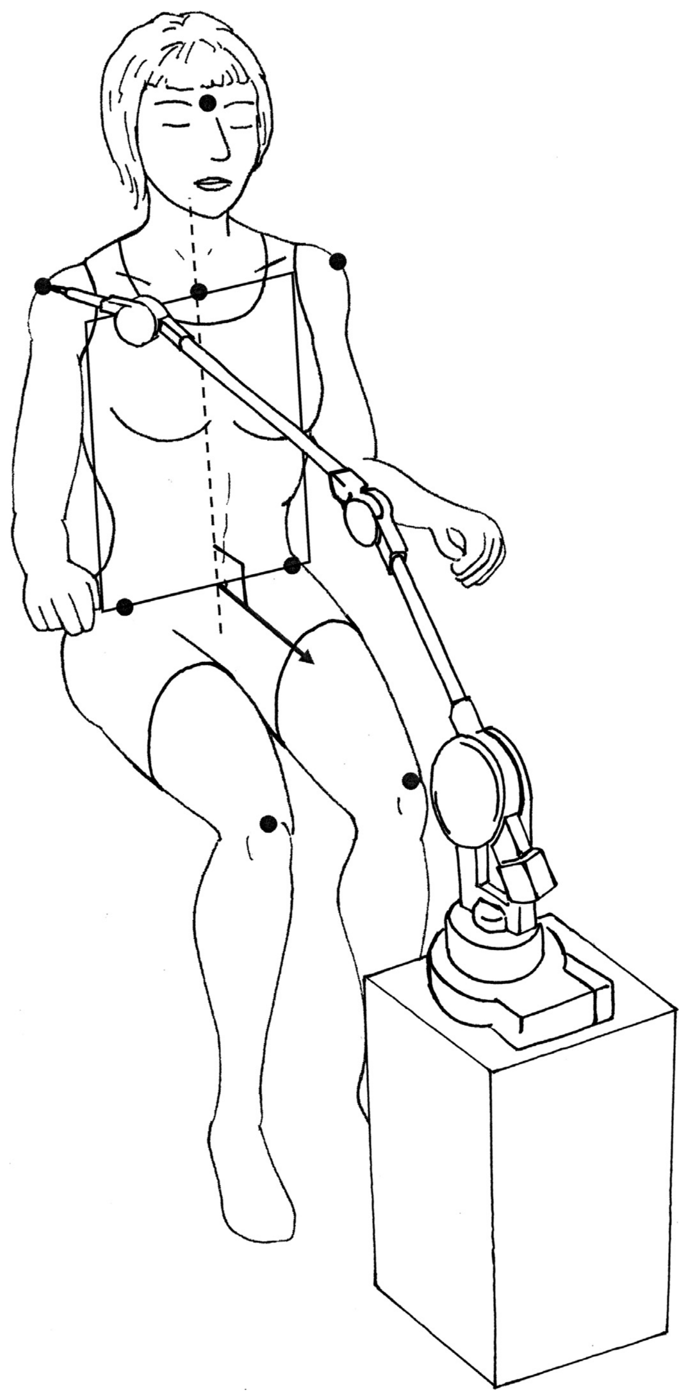

Fig. 1. Location of palpable anatomical landmarks (shown as black dots) and positioning of MicroScribe articulated arm measuring machine. The x-axis of the body-based system is indicated by the black arrow and the plane defined from the ASIS and clavicle points is also illustrated.

$$r_x = -\sin^{-1} y_z, \quad (1)$$

$$r_y = -\sin^{-1}\left(\frac{x_z}{\cos r_x}\right), \quad (2)$$

$$r_z = \sin^{-1}\left(\frac{y_x}{\cos r_x}\right). \quad (3)$$

The resulting angles are then used to transform the co-ordinates of each anatomical point into the body-based system