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A video based method to quantify posture of the head and trunk in sitting

María B. Sánchez[a,*], Ian Loram[a], John Darby[b], Paul Holmes[c], Penelope B. Butler[c,d]

[a] School of Healthcare Science, Manchester Metropolitan University, Manchester, UK
[b] School of Computing Mathematics and Digital Technology, Manchester Metropolitan University, Manchester, UK
[c] Health, Exercise and Active Living (HEAL), Manchester Metropolitan University, Cheshire, UK
[d] The Movement Centre, Robert Jones and Agnes Hunt Hospital, Oswestry, Shropshire, UK

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ABSTRACT

Maintenance of a vertically aligned posture of the head and trunk in sitting is a fundamental skill that demonstrates the presence of neuromotor control. Clinical assessments of posture are generally subjective. Studies have quantified posture using different technologies, but the application of such technologies in a clinical environment remains difficult. Video recordings, however, are easily used clinically and have potential for quantitative analysis of movement. This study used a video-based method to generate a numerical measure of postural alignment of the head and trunk in sitting. Static and dynamic trials of 12 healthy seated adults were simultaneously recorded with a sagittal video camera and a 3D motion capture system. Segmental angles were calculated for the Head, Neck and six Trunk segments. An agreed definition of aligned static sitting posture agreed was used by five clinically experienced experts to identify video frames where the participants' posture was aligned. The five subsets of frames that defined the aligned posture were combined to give aligned segments (mean ± SD) for each participant. Agreement between experts in the definition (mean) of aligned segmental angles was excellent (ICC = 0.99) and intra-assessor reliability (SD) lay within 2.1°–11.6°. Agreement between the video-based method and the 3D system was below 3.8° and 8.4° for static and dynamic trials respectively. This video-based method allowed the quantification of sitting posture and provided greater detail of the trunk/spinal profile than previous methods. It has potential as a complementary tool, alongside subjective assessments, for patients with a wide variety of pathologies.

1. Introduction

Cerebral Palsy (CP) is a neurodevelopmental condition beginning in early childhood and persisting through the lifespan. It is characterised by a disorder of movement and posture due to non-progressive brain damage; poor motor control of the head and trunk is a common feature [1–3]. Maintenance of a vertically aligned posture of the head and trunk is fundamental to activities such as sitting or standing and requires good neuromuscular control for its achievement. Assessment of postural alignment is thus essential in order to develop an accurate therapeutic plan to target promotion of head and trunk control. During assessments, the trunk is usually considered as a single unit; however, tests such as the Segmental Assessment of Trunk Control (SATCo) [4] (used at The Movement Centre, Oswestry, UK) provides detail of control status of six trunk segments, and of free sitting if a child is able to do so. Although the SATCo has good inter- and intra-rater reliability [4], it remains a subjective assessment in common with visual and other standardised assessments of alignment [5]. Objective quantification is desirable to address the limitations of subjective assessments, to quantify changes in patients that result from therapeutic intervention, or monitor the progression of a neuromuscular condition.

Various methods of quantifying aligned sitting posture are suitable in a research environment. Translation of these methods to a clinical environment is, however, difficult. Three-dimensional (3D) motion capture systems, for example, require the markers to be constantly visible to allow the segment reconstruction. Assessment of head and trunk control in children with CP can often only be achieved with at least two people surrounding the child, especially if the child cannot sit unaided. This inevitably means that some markers are obscured thus affecting accuracy of

* Corresponding author.
E-mail address: maria.b.sanchez@stu.mmu.ac.uk (M.B. Sánchez).

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measurement. Additionally, 3D motion capture systems are expensive with demanding data collection protocols and processing making them impractical in a clinical context. Nevertheless, they remain a 'gold standard' for validation of other measurement systems. The most practical clinical method has been the use of video recordings since they require minimal technical and patient preparation and can be used with all ages and severity of disability. The quantification of these video assessments is, however, essential.

This study is part of a wider investigation involving children with cerebral palsy. The aim of the study reported here was to develop a video-based method to quantify seated postural alignment of the head and trunk and to be able to identify any deviation from the aligned posture. To do this we defined the concept of alignment used to assess control, and demonstrated the accuracy of the video-based method against the gold standard for motion capture. We used a group of healthy adults for this preliminary study in order to eliminate the complications associated with compromised motor control and ensure system accuracy. The application to children with cerebral palsy provides one example of the general relevance of this concept and method.

2. Methods

2.1. Ethics

This study was a preliminary technical component to a wider investigation involving children with cerebral palsy. Ethical approval for the complete study was obtained from the NHS Health Research Authority (NRES Committee South Central, United Kingdom) and from the University Ethics Committee. The study was conducted in accordance with the Declaration of Helsinki guidelines.

2.2. Participants

Twelve adults (6 male, 6 female, mean age 27.9 ± 3.5 years, mean height 1.72 m ± 0.08, and weight 71.8 kg ± 11.8) were recruited to the study. All participants were healthy, did not report any fixed bony deformity or other structural problem of the spine, and had a body mass index less than 29 kg m^{-2}. All participants gave written informed consent for participation in this study.

All the participants wore tight fitting clothing; men were asked to leave their upper body free of clothing, women were asked to wear a customised vest that had the back removed. A clear view of the back allowed for more accurate palpation and marking of the spinous processes of the relevant vertebrae for Vicon (Vicon Nexus, Oxford Metrics, Oxford, UK) marker placement, and avoided possible artefacts generated by the movement of clothes.

2.3. Procedures

Participants sat on a bench free of back or arm support. The height of the bench was adjusted to ensure participants' feet were flat on the floor and the knees and hips were flexed at 90°. Participants were instructed that the initial trial position was with the hands in the air at shoulder height with elbows extended; a common posture used to assess trunk control in children with cerebral palsy. Data recording began before the hands were lifted to the trial position and ended when the hands were placed down again. This ensured that there were no missing data, and that only the data collected with hands in the trial position were analysed.

Participants were asked to sit upright, and verbal and manual feedback was given to achieve an initial aligned posture in sitting. Two different trials were collected, static and dynamic, to replicate physical therapy tests of control. For the static trials, participants were asked to remain still for 10 s in upright sitting with the hands in the trial position. For the dynamic trials, participants were asked to flex, side-flex or extend their head and trunk, returning to upright sitting after a couple of seconds and between each directional movement. This dynamic component enabled video quantification to identify deviation from the aligned posture. Lateral movements were included to represent the clinical situation more fully.

2.4. Apparatus and measurements

Data were collected simultaneously using a 3D motion capture system and one video camera recording sagittal plane movements.

2.4.1. 3D motion capture

Motion data was collected using a ten-camera system (Vicon) at a frequency of 100 Hz. Reflective markers were used to define eight segments (Fig. 1): Head, Neck, Upper-Thoracic (UT), Mid-Thoracic (MT), Lower-Thoracic (LT), Upper-Lumbar (UL), Lower-Lumbar (LL) and Pelvis. An additional marker on the left elbow was used to identify the trial position of the arm. Marker location and segment definition were based on the description of the SATCo trunk segments [4].

Marker reconstruction and gap filling was performed using Vicon-Nexus software (version 1.8.5). Processing was performed using Visual 3D (v.5.01, C-motion, Germantown, MD, USA); a low-pass filter at 6 Hz was used to filter marker trajectories, and segmental angles were calculated. A segmental angle was defined as the angle between a given segment and the absolute coordinate system and was calculated for each of the segments defined. Only the sagittal component of the segmental angles was taken into consideration. Data was exported to Matlab (Mathworks, Cambridge, MA) for further analysis.

2.4.2. Video recording

One video camera (JVC, HD Everio RX110) mounted on a levelled tripod was placed on the left side of the participant at a constant distance of 3.80 m and constant height of 0.90 m. Video was recorded at 25 Hz. Small coloured blocks (2 × 2 × 2 cm) were used to improve the lateral visualization and tracking of the back landmarks (Fig. 1). The blocks were placed 1.5 cm to the left of the equivalent reflective marker. Some of the reflective markers were also used for video tracking.

Coordinates of landmarks from video were obtained using the Dartfish marker tracking tool (Dartfish 7, TeamPro 7.0). The same operator processed all videos. Trunk segments were created using a customised Matlab code, with each segment defined as the vector joining two consecutive landmarks. Segmental angles were estimated and defined within the sagittal plane in relation to the vertical.

2.5. Data processing and analysis

The Vicon and the video signal were synchronised prior to analysis using an initial manual synchronisation followed by an automated fine-tuning using cross correlation.

For both systems, positive angles represented anterior inclination relative to the vertical, and detrended and absolute angles were calculated. The detrended angles (D) showed each angle relative to the mean angle for that trial. The absolute angles (A) for all trials were calculated relative to a single value of aligned angle defined by the participant model of alignment (see below). D angles revealed movement of segments within the trial while excluding drift in position between trials. A angles revealed