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An alternative technical marker set for the pelvis is more repeatable than the standard pelvic marker set

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ABSTRACT

Multiple marker sets and models are currently available for assessing pelvic kinematics in gait. Despite the presence of a variety models, there are still debates on their reliability and consistency, and consequently there is no clearly defined standard. Two marker sets were evaluated in this study: the 'Traditional' where markers are placed at the anterior and posterior superior iliac spines (ASISs, PSISs); and the 'Cluster', where a cluster of three orthogonal markers fixed on a rigid based is attached to the sacrum. The two sets were compared with respect to intra and inter session standard deviations of maximum pelvic tilt, obliquity and rotation angles. The repeatability between and within sessions was measured using coefficient of multiple correlation (CMC). Also the similarity between the two sets was assessed using inter-protocol CMC (ipCMC). Both data sets generated showed high within and between session repeatability in the sagittal plane (CMC > 0.80), although the Cluster method showed higher repeatability than that of the Traditional method in non-sagittal plane motion for both within and between sessions. The authors are not aware of other studies reporting the differences in intra and inter session variability and repeatability values for different body mass index categories such as overweight and obese subjects with relatively large sample size. Hence the Cluster method overcomes a number of theoretical and experimental limitations such as minimising the marker occlusion and is a reliable alternative to the Traditional (the standard) marker set.

1. Introduction

Over the past decade the understanding of pelvic kinematics during gait has increased despite a lack of clearly defined measurement standards. The most commonly used model in gait analysis is the kinematic model described by Kadaba et al. [1] and Davis et al. [2]. In the latter model, calculation of lower limb kinematics is based on the anterior superior iliac spines (ASIS) therefore occlusion of these markers for all or part of the trial will result in loss of some data. Occlusion of the ASIS could be as a result of soft tissue around the anterior abdomen (a common issue in overweight and obese subjects), arm movement, or activities that require high degrees of hip and trunk flexion, such as running, stair climbing or level walking [3]. One known modification to overcome ASIS occlusion is to introduce two technical markers to the pelvis positioned an equal distance laterally and posteriorly to the ASIS marker (often placed on the iliac crest) [4]. In order to use these technical markers, the ASIS marker positions can be expressed in relation to a technical coordinate system created using the technical markers in a static trial where the subject is stationary for couple of seconds with both anatomical and technical markers on the pelvis. However, having these technical markers on the lateral side of the waist does not guarantee reliable results, as again this is a site for fat deposition and substantial amount of fat and skin tissue may be present. There are no reports on how this method could be reliable for overweight and obese subjects. Generally, in the previous studies there has been no reporting on how to minimise the soft tissue artefact for overweight and obese subjects performing range of motion activities. Another previously used method involved a triad of markers directly placed on the posterior aspect of the pelvis. This was used to define directly the pelvic anatomical coordinate frame [5,6]. Pohl et al. [6] similarly used a rigid triad of markers to

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describe pelvic kinematics with the addition of two markers on the iliac crest, noting that this may not be the most reliable method to define the frontal plane of the pelvis [6]. This study proposed a potential solution to this problem which is the use of a cluster of three orthogonal markers attached to a rigid based as technical markers. This cluster is attached to the sacrum (Fig. 1) as this provides more accurate results than the ASIS and has less skin artefact [7]. Using the 'calibrated anatomical system technique' (CAST) [8,10] allows the position of ASIS defined relative to the Cluster in a static trial and then during dynamic trial the position of the ASIS is linked to the Cluster and thus affected by the same skin movement artefact that affects the Cluster [11]. The aim of this study is to compare the Cluster method with the Traditional method, which is the use of four surface markers on the right and left anterior superior iliac spine and left and right posterior superior iliac spine, in a population of healthy volunteers with varying body mass index (BMI).

2. Methodology

2.1. Participants

Thirty healthy subjects participated in this study (mean ± SD age and body mass index of 32.5 ± 12.3 years, and 26.39 ± 4.20 kg/m^2, respectively). They were divided in three equal groups of normal, overweight, and obese according to their body mass index (BMI) (normal 19–24 kg/m^2, overweight 24–28 kg/m^2, and obese 28–35 kg/m^2). None of the subjects had any history of lower back pain, surgery on the hip or lower limbs. They had no musculoskeletal injuries or disorders that affect walking ability. Written informed consent was obtained prior to participation. This study was approved by the Imperial College Research Ethics Committee (ICREC).

2.2. Data collection

An optical motion tracking system (VICON, Oxford, UK) consisting of nine high speed MX-13+ cameras was used at acquisition rate of 150 Hz. The same assessor carried out all data collection and analysis. Spherical reflective markers of 14 mm in diameter were applied concurrently (Fig. 1): (a) RASIS, LASIS, LPSIS, and RPSIS (Traditional); (b) a rigid cluster of three markers on sacrum (Cluster). In addition, three markers were attached to boney landmarks on the right and left foot to

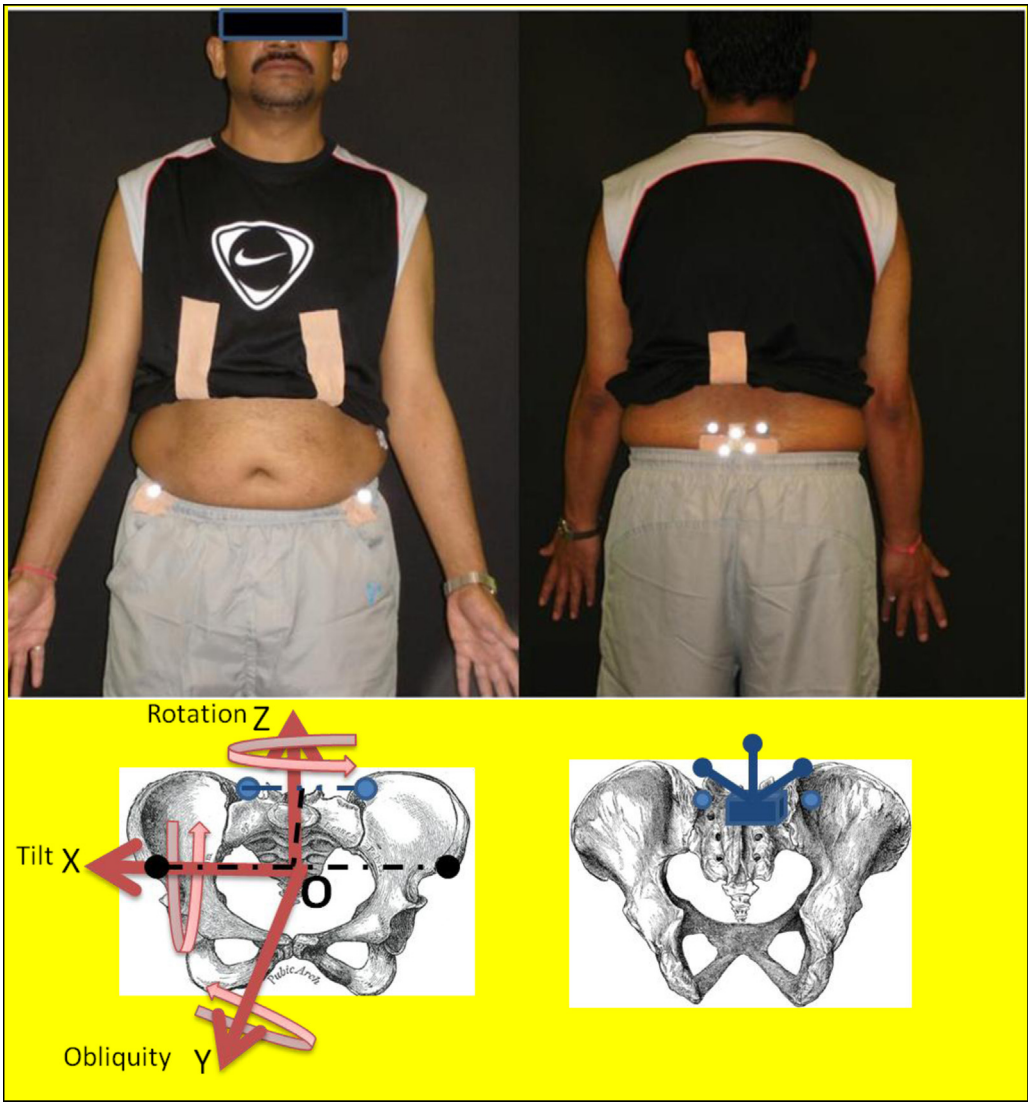

Fig. 1. Shows the markers placed on boney landmarks of the pelvis. Top left picture shows the anterior view of a subject with two markers on the ASIS and top right picture shows the posterior view of two markers placed on the PSIS and the cluster of three markers attached to the sacrum. For the Traditional set four anatomical markers are used to track the motion (two black circles = left/right ASIS and two light blue circles = left/right PSIS are shown on the skeleton) while for the Cluster method, a separate cluster positioned on sacrum is used for tracking the pelvic movement which is shown by blue colour on the bottom left picture. Coordinate frame of the pelvis is in red. Pelvic tilt represents the movement of the pelvis around the *X* axis (flexion/extension), pelvic obliquity shows the movement of the pelvis around the *Y* axis (Abduction/adduction), and finally pelvic rotation stands for the movement of the pelvis around the *Z* axis. The origin of the segment is defined as the midpoint between two ASIS, *X* axis defined as a line parallel to the ASIS ( ) and the *Y* axis is defined as a line connecting the midpoints of ASIS and PSIS (- - - - - -). The *Z* axis is orthogonal to other two axes. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)