



## Short communication

## Evaluation of alternative technical markers for the pelvic coordinate system

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## ABSTRACT

In this study, we evaluated alternative technical markers for the motion analysis of the pelvic segment. Thirteen subjects walked eight times while tri-dimensional kinematics were recorded for one stride of each trial. Five marker sets were evaluated, and we compared the tilt, obliquity, and rotation angles of the pelvis segment: (1) standard: markers at the anterior and posterior superior iliac spines (ASIS and PSIS); (2) markers at the PSIS and at the hip joint centers, HJCs (estimated by a functional method and described with clusters of markers at the thighs); (3) markers at the PSIS and HJCs (estimated by a predictive method and described with clusters of markers at the thighs); (4) markers at the PSIS and HJCs (estimated by a predictive method and described with skin-mounted markers at the thighs based on the Helen-Hayes marker set); (5) markers at the PSIS and at the iliac spines. Concerning the pelvic angles, evaluation of the alternative technical marker sets evinced that all marker sets demonstrated similar precision across trials (about 1°) but different accuracies (ranging from 1° to 3°) in comparison to the standard marker set. We suggest that all the investigated marker sets are reliable alternatives to the standard pelvic marker set.

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## 1. Introduction

In human movement analysis, describing the movement of the pelvis is accomplished through a pelvic anatomical coordinate system most commonly defined by use of surface markers placed on the right and left anterior superior iliac spines (RASIS and LASIS) and on the right and left posterior superior iliac spines (RPSIS and LPSIS). The pelvic anatomical coordinate system can be described as the origin at the midpoint between RASIS and LASIS, the Z-axis points from the origin to the RASIS, the X-axis lies in the plane defined by the RASIS, LASIS, and the midpoint of the RPSIS and LPSIS markers and points ventrally orthogonal to the Z-axis, and the Y-axis is orthogonal to these two axes (Wu et al., 2002), as shown in Fig. 1. This marker placement has been the de facto standard for human movement analysis of the pelvis segment.

Given the difficulty of measuring the position of the RASIS and LASIS markers due to occlusion by the arms or by skin tissue from the abdominal area during movement, alternative technical markers have been used during motion trials. In order to use these technical markers, a static trial, where the subject stands still with both anatomical and technical markers on the pelvis, must be performed first. After that, the RASIS and LASIS markers can be removed; hence, the position of these markers can be

expressed in relation to a technical coordinate system (TCS) created using the technical markers. A common solution is to place technical markers at the right and left lateral iliac crests (RIC and LIC). However, the markers at the RIC and LIC still might be occluded by the arms and might not produce reliable results given that they are placed on the lateral of the waist, where a good amount of fat and skin tissue may be present. We are unaware of any work that has evaluated the reliability of using the RIC and LIC markers. Another alternative to solve the problems listed above is to use the right and left hip joint centers described in the TCS of the right and left thighs, together with the RPSIS and LPSIS markers, as technical markers for tracking the pelvis movement. Here, we report a kinematic evaluation of these alternative technical markers for the motion analysis of the pelvic segment.

## 2. Methods

Thirteen healthy adults (mean  $\pm$  SD age, height, and mass of  $27.8 \pm 5.7$  yr,  $1.71 \pm 0.08$  m, and  $69.3 \pm 12.3$  kg) participated in this study. This study was approved by the ethics committee of Instituto Vita.

To test the alternative pelvic technical markers, we kept the standard pelvic anatomical coordinate system described earlier and the following pelvic technical marker sets were evaluated: (a) RASIS, LASIS, RPSIS, and LPSIS (the standard); (b) right and left hip joint centers (RHJC and LHJC) described in the thigh TCS, RPSIS, and LPSIS; and (c) RIC, LIC, RPSIS, and LPSIS.

The type of marker set used to describe the motion of the thigh may affect the second pelvic marker set. In order to investigate this effect, two marker sets were investigated: the Helen-Hayes marker set (Kadaba et al., 1990) and a marker set composed of rigid clusters to define the segmental TCS (Cappozzo et al., 1995). For the Helen-Hayes marker set, an extra non-collinear marker was placed on each thigh to compose a TCS in each segment. For the cluster marker set, each cluster was formed by

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We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

#### Appendix A. Supporting material

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.jbiomech.2009.09.050](https://doi.org/10.1016/j.jbiomech.2009.09.050).

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