

Gait and Posture 13 (2001) 1-6



www.elsevier.com/locate/gaitpost

# Technical note

# Pelvic angles: a mathematically rigorous definition which is consistent with a conventional clinical understanding of the terms

# Richard Baker \*

Gait Analysis Service, Musgrave Park Hospital, Stockman's Lane, Belfast BT9 7JB, Northern Ireland, UK Received 25 May 2000; received in revised form 11 July 2000; accepted 26 July 2000

#### Abstract

The most common definition of pelvic angles in conventional gait analysis uses the sequence *tilt, obliquity, rotation*. This is used in most commercially available gait analysis software. This definition of angles, however, is not in agreement with the conventional clinical understanding of the terms when both tilt and rotation are large. This paper shows that by using the sequence *rotation, obliquity, tilt* it is possible to make a mathematically rigorous definition of pelvic angles which it is consistent with that conventional clinical usage. A model of the pelvis in which the hips are maintained level is developed. It is shown that as tilt and rotation are varied, in a clinically relevant range, that obliquity measured using the conventional sequence can be as much as  $10^{\circ}$ . By definition it is  $0^{\circ}$  for the new sequence. A case study shows that measures of obliquity correlate better with the relative height of the hips using the new sequence than the conventional one. It is proposed that use of the new sequence would lead to data which is easier to interpret clinically.  $\bigcirc$  2001 Elsevier Science B.V. All rights reserved.

Keywords: Gait analysis; Pelvic angles; Cardan angles

## 1. Introduction

Kadaba et al.[1] and Davis et al.[2] independently suggested that joint angles in gait analysis should be represented as Cardan angles. These can be considered as a series of rotations, about orthogonal axes fixed in the distal segment, which change the alignment of the segment axis system from that of the proximal segment to that of the distal segment. This can be shown to be equivalent to the approach of Grood and Suntay [3] in which the first rotation is described as being about an axis fixed in the proximal segment, the final rotation about an axis fixed in the distal segment and the middle rotation about a 'floating' axis mutually perpendicular to the other two axes [4]. The movement of the pelvis is described in equivalent terms with the pelvis considered as the distal segment and the laboratory reference system as the proximal system. The rotations about the

It is well known that the value of these angles is dependent on the order in which they are specified. From a mathematical point of view all of the six possible sequences of the three angles are equivalent, there is no reason for choosing one sequence over any other. However, if these mathematically derived angles are to correspond to conventionally defined anatomical terms then the sequence is important. Wu and Cavanagh [5] suggested that the orientation of any segment with respect to the laboratory should always be described using the sequence which corre-

axes embedded in the pelvis are described as *tilt*, about

the medio-lateral axis, *obliquity*, about the anterior-superior axis and *rotation* about the proximal-distal axis.

of any segment with respect to the laboratory should always be described using the sequence which corresponds to *tilt*, *rotation*, *obliquity* (TRO) for the pelvis. Crawford et al.[6] made a strong case that the appropriate sequence will depend on joint geometry and existing clinical conventions for describing rotations and hence will be different for different joints. The sequence *flexion*, *abduction*, *internal rotation* is logical for the hip and knee and therefore many commercial gait analysis soft-

<sup>\*</sup> Tel.: +44-28-90669501 ext. 2155/2849; fax: +44-28-90382008. *E-mail address:* richard.baker@greenpark.n-i.nhs.uk (R. Baker).

<sup>0966-6362/01/\$ -</sup> see front matter @ 2001 Elsevier Science B.V. All rights reserved. PII: S0966-6362(00)00083-7

motor. There is an argument that for the sake of standardisation the accepted convention should be continued. It is the feeling of the author, however, that the advantages of having measures of pelvic rotation which correlate precisely with conventional anatomical definitions are greater than those conferred by adhering to accepted practices. For the first time in our clinical practice, we are making meaningful inferences from our pelvic obliquity data for patients with concomitant tilt and rotation.

## Acknowledgements

The author would like to thank Drs Roy Davis and Brona McDowell for reading the early versions of the manuscript and making many useful suggestions.

## References

- Kadaba MP, Ramakrishnan HK, Wootten ME. Measurement of lower extremity kinematics during level walking. J Orthop Res 1990;8:383–92.
- [2] Davis RB, Ounpuu S, Tyburski D, Gage JR. A gait analysis data collection and reduction technique. Hum Mov Sci 1991;10:575– 87.
- [3] Grood ES, Suntay WJ. A joint co-ordinate system for the clinical description of three-dimensional motions: application to the knee. J Biomech Eng 1983;105:136–44.
- [4] Chao EYS. Justification of tri-axial goniometer for the measurement of joint rotation. J Biomech 1980;13:989–1006.
- [5] Wu G, Cavanagh PR. ISB recommendations for standardisation in the reporting of kinematic data. J Biomech 1995;28:1257–61.
- [6] Crawford NR, Yamguchi GT, Dickman CA. Methods for determining spinal flexion/extension, lateral bending, and axial rotation from marker co-ordinate data: Analysis and refinement. Hum Mov Sci 1996;15:55–78.