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A comparison of hip joint centre localisation techniques with 3-DUS for clinical gait analysis in children with cerebral palsy

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ABSTRACT

Functional calibration techniques have been proposed as an alternative to regression equations for estimating the position of the hip within the pelvic co-ordinate system for clinical gait analysis. So far validation of such techniques has focussed on healthy adults. This study evaluated a range of techniques based on regression equations or functional calibration procedures techniques in 46 children representative of those attending a major clinical gait analysis service against previously validated 3-D ultrasound techniques for determining the hip joint centre. Best agreement with ultrasound for the position of the hip within the pelvic coordinate system was found for the Harrington equations (mean 14 mm, sd 8 mm). Sphere fitting (mean ≈ 22 mm, sd 11 mm) performed better than transformational techniques applied locally (mean ≈ 33 mm, sd 12 mm) or globally (mean = 30 mm, sd 14 mm). The participants with cerebral palsy showed reduced range of movement compared with healthy adults. Differences between these results and studies modelling the effects of simulated noise on functional techniques can probably be attributed to differences between that noise and the soft tissue displacements that are actually occurring.

1. Introduction

Most clinical gait analysis still uses the regression equations suggested by Davis et al. [1] to estimate the position of the hip joint centre in the pelvic coordinate system. Alternatives are Harrington's regression equations [2] or three categories of functional calibration methods [3–9]. The earliest [10,11] used *sphere fitting* algorithms based on the assumption that the co-ordinates of a thigh marker will map out a part of the surface of a sphere during movement if measured in the pelvic co-ordinate system. More recently *transformational* techniques in which joint parameters are optimised to give a best least squares fit between modelled and measured markers have been proposed [4,7]. *Global* calibration applies transformational techniques to all the modelled joints simultaneously [12,13]. These techniques have been used in several studies using simulated data [3,4,8,9] and to establish repeatability [9,13].

Studies comparing results with medical imaging data allow an assessment of the accuracy of the techniques. Two studies have compared results with bi-planar radiography [6,11] and a further two with planar ultrasound [6] and three dimensional reconstructions from planar ultrasound [14]. The equations of Davis et al. [1] appear least accurate in predicting the hip joint centre position. Three recent studies suggest that functional methods are better [5,6,14] but the most recent suggests that Harrington's regression equations perform similarly well.

All of these studies have been on healthy adults. The aim of this study is to investigate the accuracy of both the regression equations and a range of functional calibration techniques on a representative sample of children attending for routine clinical gait analysis appointments most of whom have cerebral palsy.

2. Methods

53 children aged between 5 and 18 years referred for routine clinical gait analysis were recruited (sample size was based upon results of a previous study [15]). Most had cerebral palsy. Ethical approval had been obtained from the local Human Research Ethics Committee and informed consent was obtained from families.

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allow for a greater range of hip movement in the calibration exercises. However, there was some concern that the act of sitting on the seat might introduce a soft tissue artefact around the pelvis. Despite this, similarities in findings with the previous study using comparable techniques without the stand [14] indicate that this would not be an issue.

5. Conclusion

This study on a considerable number of children typical of those attending clinical gait analysis services showed that the Harrington regression equations perform better than the Davis equations in locating the hip joint centre. They also performed better than a variety of functional calibration techniques in terms of mean error and the percentage of hips with an error falling below 10, 20 or 30 mm. Within the functional approaches sphere fitting techniques perform better than transformational techniques.

Conflict of interest statement

The authors have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gaitpost.2012.03.011.

References

[1] Davis RB, Õunpuu S, Tyburski D, Gage JR. A gait analysis data collection and reduction technique. Human Movement Science 1991;10(5):575–87.
[2] Harrington ME, Zavatsky AB, Lawson SEM, Yuan Z, Theologis TN. Prediction of the hip joint centre in adults, children, and patients with cerebral palsy based on magnetic resonance imaging. Journal of Biomechanics 2007;40(3):595–602.
[3] Camomilla V, Cereatti A, Vannozzi G, Cappozzo A. An optimized protocol for hip joint centre determination using the functional method. Journal of Biomechanics 2006;39(6):1096–106.
[4] Ehrig RM, Taylor WR, Duda GN, Heller MO. A survey of formal methods for determining the centre of rotation of ball joints. Journal of Biomechanics 2006;39(15):2798–809.
[5] Hicks JL, Richards JG. Clinical applicability of using spherical fitting to find hip joint centers. Gait and Posture 2005;22(2):138–45.
[6] Leardini A, Cappozzo A, Catani F, Toksvig-Larsen S, Petitto A, Sforza V, et al. Validation of a functional method for the estimation of hip joint centre location. Journal of Biomechanics 1999;32(1):99–103.
[7] Piazza SJ, Erdemir A, Okita N, Cavanagh PR. Assessment of the functional method of hip joint center location subject to reduced range of hip motion. Journal of Biomechanics 2004;37:349–56.
[8] Piazza S, Okita N, Cavanagh P. Accuracy of the functional method of hip joint center location: effects of limited motion and varied implementation. Journal of Biomechanics 2001;34:967–73.
[9] Schwartz MH, Rozumalski A. A new method for estimating joint parameters from motion data. Journal of Biomechanics 2005;38(1):107–16.
[10] Cappozzo A. Gait analysis methodology. Human Movement Science 1984;3:27–50.
[11] Bell AL, Pederson DR, Brand RA. A comparison of the accuracy of several hip centre location prediction methods. Journal of Biomechanics 1990;23(6):617–21.
[12] Lu TW, O'Connor JJ. Bone position estimation from skin marker co-ordinates using global optimisation with joint constraints. Journal of Biomechanics 1999;32(2):129–34.
[13] Charlton IW, Tate P, Smyth P, Roren L. Repeatability of an optimised lower body model. Gait and Posture 2004;20(2):213–21.
[14] Sangeux M, Peters A, Baker R. Hip Joint Center localization: evaluation on normal subjects in the context of gait analysis. Gait and Posture 2011;34(3):324–8.
[15] Peters A, Baker R, Sangeux M. Validation of 3-D freehand ultrasound for the determination of the hip joint centre. Gait and Posture 2010;31:530–2.
[16] Woltring HJ. On optimal smoothing and derivative estimation from noisy displacement data in biomechanics. Human Movement Science 1985;4(3):229–45.
[17] Chang LY, Pollard NS. Constrained least-squares optimization for robust estimation of center of rotation. Journal of Biomechanics 2007;40(6):1392–400.
[18] McGinley JL, Baker R, Wolfe R, Morris ME. The reliability of three-dimensional kinematic gait measurements: a systematic review. Gait and Posture 2009;29(3):360–9.