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Comparison of kinematic and kinetic parameters calculated using a cluster-based model and Vicon's plug-in gait

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Abstract

Gait analysis is an important clinical tool. A variety of models are used for gait analysis, each yielding different results. Errors in model outputs can occur due to inaccurate marker placement and skin motion artefacts, which may be reduced using a cluster-based model. We aimed to compare a custom-made cluster model (ClusBB) with Vicon's plug-in gait. A total of 21 healthy subjects wore marker sets for the ClusBB and plug-in gait models simultaneously while walking on a 6-m walkway. Marker and force plate data were captured synchronously and joint angles/moments were calculated using both models. There was good correlation between the models (coefficient of multiple correlations > 0.65) and good intra-session correlation for both models (coefficient of multiple correlations > 0.80). Inter-subject variability was high, ranging from 15° to 40° in the sagittal plane and 11° to 52° in the coronal and transverse planes. Intra-subject variability was small for both ClusBB and plug-in gait models. Inter-subject variance tended to be high in both models for knee abduction/adduction, but particularly so for plug-in gait, suggesting that a cluster-based model may reduce the variability. The inter-subject variance in out-of-sagittal plane data is of particular importance clinically, given the reliance on these datasets in clinical decision-making.

Keywords

Biodynamics, clinical outcome prediction, gait analysis, joint biomechanics, modelling/simulation (biomechanics)

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Introduction

Gait analysis has become an important clinical tool for planning and evaluating interventions, as well as for improving sports performance and reducing injury. It is therefore important that the biomechanical models used are valid. Different protocols are known to yield different results,[1,2] specifically for out-of-sagittal plane rotations.[1] In the assessment of medial knee osteoarthritis (OA), knee adduction angles and moments are considered key parameters.[3,4] Given the relatively small coronal plane knee motion, measurement variability is problematic. Further errors are known to occur due to skin motion artefacts and inaccuracies in marker placement.[5,6]

The most commonly utilised model in optical gait analysis is the 'Newington' model,[5,7] on which Vicon's plug-in gait (PiG; Vicon Motion Systems, Oxford, UK) is based. PiG incorporates 16 markers, making it a useful model for clinical investigations. However, placement of the thigh and calf markers is critical for correct alignment of the knee joint axis.[8] Inaccurate location of anatomical markers can result in large inter-subject variability in model outputs. When the inter-subject variability of control data becomes greater than the expected change due to pathology, the clinical usefulness of the data becomes doubtful. Few studies report inter-subject variability, particularly considering the effects of different computational models.

In order to reduce this variability, other studies have defined anatomical landmarks relative to clusters,[9] which are less reliant on accurate marker placement; however, this can still result in inaccurate identification of joint centres.[10] Our group has developed a model, which calculates kinematics using clusters without identifying joint centres.[11] Based on these principles, a

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Table 2. Intra- and inter-subject MAV and MRV for angles at the hip, knee and ankle joints.

		Hip			Knee			Ankle		
		Flexion/ extension	Abduction/ adduction	Rotation	Flexion/ extension	Abduction/ adduction	Rotation	Flexion/ extension	Abduction/ adduction	Rotation
Intra-MAV (°)	ClusBB	2.5 (1.0)	1.6 (0.6)	2.3 (0.7)	4.1 (1.4)	1.7 (0.8)	3.4 (3.8)	2.5 (0.7)	3.8 (1.7)	3.3 (4.3)
	PiG	2.4 (0.9)	1.5 (0.6)	2.3 (0.6)	3.4 (1.0)	1.2 (0.4)	3.2 (2.4)	3.4 (2.2)	1.4 (1.8)	3.9 (2.1)
Intra-MRV (%)	ClusBB	5.5 (2.1)	10.9 (4.6)	14.5 (6.8)	6.2 (2.0)	15.3 (6.5)	12.7 (4.8)	8.8 (2.8)	21.0 (12.5)	18.4 (6.3)
	PiG	5.5 (2.2)	11.0 (5.4)	13.0 (5.1)	5.9 (1.7)	12.3 (6.3)	17.7 (9.1)	7.3 (2.6)	16.3 (7.1)	15.9 (6.8)
Inter-MAV (°)	ClusBB	21.9	11.4	23.6	19.9	13.6	31.2	15.4	34.2	24.3
	PiG	20.4	12.7	40.9	18.3	22.1	49.7	39.4	31.3	52.4
Inter-MRV (%)	ClusBB	49.7	82.7	183.6	30.5	166.9	152.2	55.3	222.8	180.1
	PiG	47.9	90.2	262.2	32.7	439.2	387.5	75.7	376.6	282.3

MAV: mean absolute variability; MRV: mean relative variability; PiG: plug-in gait.

a knee alignment device (KAD). A comparison between the KAD and clusters, to reduce data variability, was beyond the scope of this study; however, both techniques may be utilised to reduce the variability noted in the standard PiG model.

We have shown good correlation between our ClusBB and PiG models using CMCs; however, it should be acknowledged that this technique has some limitations.[6] The inter-subject variance in out-of-sagittal plane data noted in this study is of particular importance clinically, given the reliance on these datasets in clinical decision-making, specifically for people with knee OA.

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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References

1. Ferrari A, Benedetti MG, Pavan E, et al. Quantitative comparison of five current protocols in gait analysis. *Gait Posture* 2008; 28(2): 207–216.
2. Gorton GE III, Hebert DA and Gannotti ME. Assessment of the kinematic variability among 12 motion analysis laboratories. *Gait Posture* 2009; 29(3): 398–402.
3. Andriacchi TP, Koo S and Scanlan SF. Gait mechanics influence healthy cartilage morphology and osteoarthritis of the knee. *J Bone Joint Surg Am* 2009; 91(Suppl. 1): 95–101.
4. Miyazaki T, Wada M, Kawahara H, et al. Dynamic load at baseline can predict radiographic disease progression in medial compartment knee osteoarthritis. *Ann Rheum Dis* 2002; 61(7): 617–622.
5. Kadaba MP, Ramakrishnan HK, Wootten ME, et al. Repeatability of kinematic, kinetic, and electromyographic data in normal adult gait. *J Orthop Res* 1989; 7(6): 849–860.
6. McGinley JL, Baker R, Wolfe R, et al. The reliability of three-dimensional kinematic gait measurements: a systematic review. *Gait Posture* 2009; 29(3): 360–369.
7. Davis RB III, Õunpuu S, Tyburski D, et al. A gait analysis data collection and reduction technique. *Hum Movement Sci* 1991; 10: 575–587.
8. Vicon Motion Systems. *Plug-in gait product guide – foundation notes*. Oxford: Vicon Motion Systems, 2010, http://www.irc-web.co.jp/vicon_web/news_bn/PIGManualver1.pdf.
9. Cappozzo A, Catani F, Croce UD, et al. Position and orientation in space of bones during movement: anatomical frame definition and determination. *Clin Biomech (Bristol, Avon)* 1995; 10(4): 171–178.
10. Holden JP and Stanhope SJ. The effect of variation in knee center location estimates on net knee joint moments. *Gait Posture* 1998; 7(1): 1–6.
11. Cleather DJ and Bull AM. Influence of inverse dynamics methods on the calculation of inter-segmental moments in vertical jumping and weightlifting. *Biomed Eng Online* 2010; 9: 74.
12. Ferrari A, Cutti AG and Cappello A. A new formulation of the coefficient of multiple correlation to assess the similarity of waveforms measured synchronously by different motion analysis protocols. *Gait Posture* 2010; 31(4): 540–542.
13. Horsman K, Koopman HF, van der Helm FC, et al. Morphological muscle and joint parameters for musculoskeletal modelling of the lower extremity. *Clin Biomech (Bristol, Avon)* 2007; 22(2): 239–247.
14. Roislien J, Rennie L and Skaaret I. Functional limits of agreement: a method for assessing agreement between measurements of gait curves. *Gait Posture* 2012; 36(3): 495–499.
15. Perry J and Burnfield J. Gait Analysis: Normal and Pathological Function. 2nd Ed. Thorofare, New Jersey: Slack Incorporated, 2010.
16. Chao EY, Laughman RK, Schneider E, et al. Normative data of knee joint motion and ground reaction forces in adult level walking. *J Biomech* 1983; 16(3): 219–233.
17. Biden E, Olshen R, Simon S, et al. Comparison of gait data from multiple labs. *Trans Orthopaedic Res Soc* 1987.