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Alternative modelling procedures for pelvic marker occlusion during motion analysis

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ABSTRACT

Background: Motion analysis of participants with different body shapes under diverse conditions can be problematic when vital markers are occluded. The markers located over the anterior superior iliac spines are commonly occluded in older patients and during analysis of activities with trunk and hip flexion which can prevent accurate calculation of lower limb joint kinematics. Options to modify standard body models exist but have not been described in detail, and the effects on the lower limb kinematics are not known.

Methods: Three-dimensional motion analysis data were collected from 10 participants during level walking. A single trial from each participant was processed using the standard PlugIn Gait model and with four alternative modelling procedures where either one or both anterior pelvis markers were not labelled for all or part of the trial. Similarity of these alternative procedures to PlugIn Gait was assessed by comparison of peak kinematic characteristics and Root Mean Square (RMS) across the gait cycle.

Findings: The peak lower limb kinematics of all four alternative modelling procedures were similar to PlugIn Gait to within 4.57°. The alternative procedure most similar to PlugIn Gait was less than 1.24° different. The largest RMS was 2.88° and the smallest was 0.92°.

Interpretation: This study has presented several options for researchers and clinicians to modify the standard body models of motion analysis so that lower limb kinematics may be calculated without reliance on continuous visualisation of anterior pelvic markers. Although the alternative modelling processes are subject to different sources of error which need to be considered, the error is minimal.

1. Introduction

The kinematic model described by Davis et al. has become one of the most commonly used models in gait analysis [1]. The popularity of this model is well documented and it has also been implemented in commercial motion analysis packages such as the Vicon Clinical Manager (more recently Vicon PlugIn Gait) (Vicon, Oxford, UK). In this model, the markers located over the anterior superior iliac spine (ASIS) are mandatory for determining the lower limb joint centres and subsequent calculation of lower limb kinematics. When these markers are occluded for all or part of the trial, lower limb kinematics cannot be determined. Occlusion of these markers is more likely to occur in older subjects whose body morphologies are more likely to be characterised by greater amounts of soft tissue around the anterior abdomen. Difficulties collecting data in these subjects during level gait have previously been documented [2]. Additionally, assessment of activities that require high degrees of hip and trunk flexion, such as running, stair climbing and cycling, may also be problematic. Kinematic analysis in these situations can occur only when there are opportunities to avoid reliance on consistent visualisation of the ASIS markers by modifying the standard modelling procedure.

One known modification to overcome the problem of occlusion of the marker indicating the ASIS marker is to move both ASIS markers an equal distance laterally and posteriorly on the pelvis (Vicon Motion Systems, Oxford, UK). It may also be possible to recreate occluded markers (as virtual markers) based on their position in relation to other visible markers on the same body segment. However, these options have not been described in detail in the literature and the kinematics derived from these procedures have not been compared to those calculated using the standard model.

Therefore, the aim of this study was to describe possible modifications to the commonly used PlugIn Gait lower limb kinematic model (Vicon Motion Systems, Oxford, UK) that do not

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reported for measurement of kinematics using three-dimensional motion analysis [6].

The similarity of all of these procedures to PlugIn Gait provides options for users of three-dimensional motion analysis in situations where one ASIS marker is not visible throughout the data collection trial (Procedure C), where both ASIS markers are visible for only some frames (more than 50) of a trial (Procedure D), or where both ASIS markers are not visible at all throughout the trial (Procedure E). In situations where each of these alternative modelling procedures is possible, it is necessary to consider the error of specific planes of movement for each procedure. For example, the lower limb kinematics derived from Procedure E more closely resembled PlugIn Gait throughout the gait cycle for all planes of movement at all joints. Therefore, creating virtual ASIS markers from calculations within the static subject calibration (Procedure E) may be most appropriate in situations that require waveform analysis. The kinematics generated by Procedures C and D more closely resembled PlugIn Gait in comparisons of the peak gait characteristics, and might be used where these are required. Although these models generated similar error in comparison to PlugIn Gait, in situations where the sagittal plane pelvis kinematics are a priority, creating a single virtual ASIS marker (Procedure C) may be preferable. Creating bilateral virtual markers (Procedure D) may be more appropriate when the sagittal kinematics of the hip are a priority.

It should be noted that all of the subjects in this study had undergone total knee replacement at approximately the same time prior to testing, and so were of similar ages and predisposed to similar physical attributes. Whilst this potentially limits the generalizability of the findings, there was nonetheless a wide range of BMI in this sample and marker visualisation has previously been reported to be difficult in this population of patients that have undergone knee replacement surgery [2].

5. Conclusion

This study has identified four alternative modelling procedures that may be used during three-dimensional data collection when the ASIS markers are occluded for all or part of the trial. The alternative modelling processes propagate different errors in different planes of movement, therefore this error must be understood prior to implementing these modelling procedures. The error associated with Procedures C–E is relatively small and provides opportunities for three-dimensional motion analysis and PlugIn Gait to be utilised in a wide range of situations.

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Conflict of interest

No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or non-profit organization with which the authors of the paper “Alternative modelling procedures for pelvic marker occlusion during motion analysis” are affiliated or associated.

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