

A Multi-Clinic, Multi-User Evaluation of Marker Resolution and Error in Gait Analysis Laboratories

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Introduction

When markers are well spaced (i.e. greater than 10 diameters) spatial resolutions of less than +/-1 mm in marker position can be realized in most gait laboratories. However, with closer spacing, it is more difficult to distinguish between markers and resolution can suffer. This study introduces a simple method for quantifying the resolution of markers with varying separation, in a dynamic situation. This test was applied at four clinics which use different motion capture systems.

Statement of Clinical Significance

Marker spacing is a problem when dealing with childrens' feet. Since their feet are smaller, markers are necessarily closer than the preferred minimum spacing of 10 diameters. The loss of resolution is compounded by the fact that the greatest amount of motion during gait occurs at the feet. Some laboratories will even decline to test feet that are shorter than 10cm long due to the uncertainty in resolution and visibility.

Methodology

Equipment

The apparatus used was a 30 cm diameter hollow plexiglass cylinder painted matte black (Figure 1a). One end was solid with holes at regular intervals along the diameter for repeatable marker placement (Figure 1b). The *fixed marker* was always at 13 mm from the cylinder edge. The *moveable marker* was placed in one of 6 positions. Two marker sets were used: small (10 mm diameter) and large (25 mm diameter). The small markers stood 35 mm out from the solid side and the large markers stood out 45 mm. Testing was performed at the Wolfe Orthopaedic Biomechanics Lab at University of Western Ontario (8 camera Motion Analysis Corp. (MAC) Eagle cameras), Motion Analysis Lab at Mayo Clinic (10 MAC Eagle cameras), Thames Valley Children's Center (London, ON, Canada; 8 MAC Falcon cameras) and Gillette Children's Hospital (St. Paul, MN, USA; 12 Vicon analog cameras).

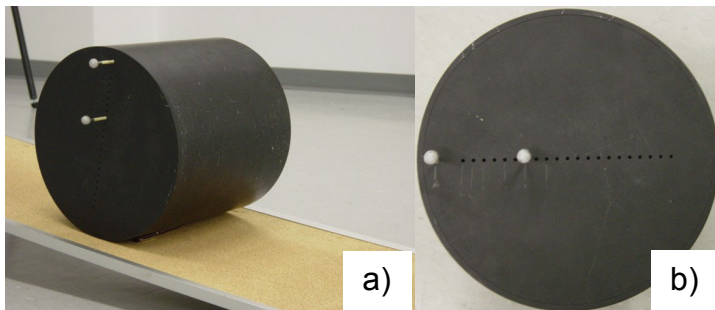


Figure 1: a) Apparatus in release position at top of ramp, b) view of markers and positioning holes.

Experimental Protocol

Testing order was randomized. A complete test included both marker sets at all 6 separation

distances. The cylinder was placed on a 1 m long ramp (10° incline). The cylinder was

released down the ramp and rolled through the capture volume. 120 samples were collected after leaving the ramp at 60 Hz with three trials per condition. Marker trajectories were tracked (Figure 2) and separation calculated. Mean separation and standard deviation (SD) were calculated through each trial. The test mimicked foot marker motion during gait with dynamic trajectories close to the ground. No special tuning or setup of cameras was needed.

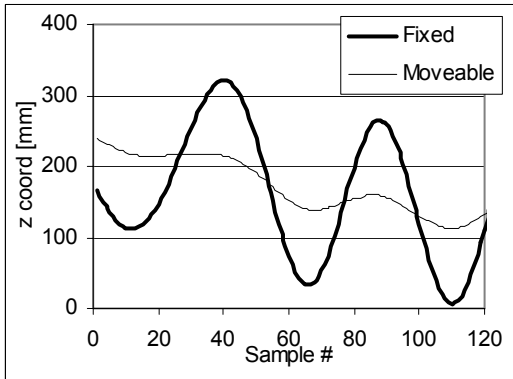
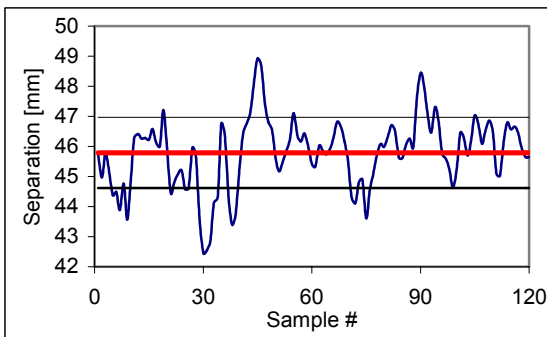


Figure 2: Trajectories of the fixed (heavy) and moveable (light) markers (vertical coordinate is shown).



Results

Calculated separation distance was not constant for all 120 samples of a trial (Figure 3). Mean separation was not constant for all three trials, but varied by less than the SD of individual trials. Therefore trial SD was used as the measure of spatial resolution. The spatial resolution was not constant with respect to the separation (Figure 4), but increased as the separation distance decreased. Spatial resolution of large markers was inferior to small markers (Figure 4). Each of the motion analysis systems tested were unable to distinguish between large markers closer than 40 mm. Small markers could be distinguished at 25 mm. System performances were also similar between testing days with different calibrations (Figure 4).

Figure 3: Calculated separation distance during a single trial with mean and +/--standard deviation.

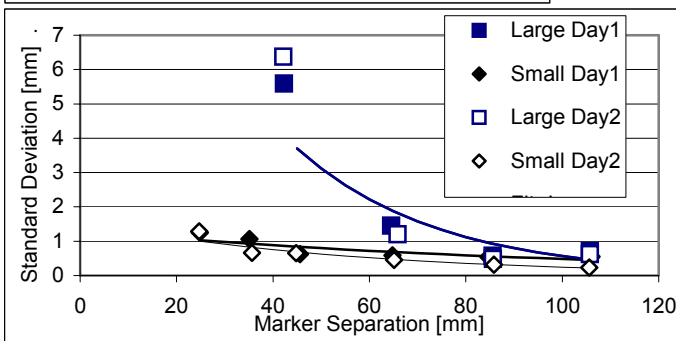


Figure 4: Standard deviation versus separation distance for small (diamonds) and large (squares) markers on two different days.

Discussion

This study has demonstrated that spatial resolution is dependent on marker separation. Even with a small marker set, although the markers

could be distinguished at separations of less than 3 diameters, resolution had diminished from about +/-0.5 mm to +/-1.25 mm. This increased error is significant when applying a small marker set to childrens' feet. The increased error with foot marker data should lead to more conservative interpretation of foot kinematics in children.