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SYSTEM DEPENDENT DIFFERENCES IN THE ACCURACY OF GAIT KINEMATICS: A COMPARISON OF A MODERN 12 CAMERA VICON MX-GIGANET SYSTEM WITH AN OLDER 8 CAMERA VICON 612 SYSTEM

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SUMMARY

This study reports a comparison of the accuracy of two 3D motion analysis systems.

INTRODUCTION

3-D human movement analysis is popularly used in the clinical and research environment as a tool for analysing human motion. Such systems allow for the reconstruction, in 3-D space, of the instantaneous position of either retro-reflective or light emitting markers positioned on the body surface of the test subject. From the position of the markers, the underlying bone position and orientation can be obtained and ultimately kinematic and kinetic data extrapolated. Our ability to describe movement is dependent on the accuracy with which the position of these markers can be reconstructed in three dimensions by the system used. The accuracy of data capture systems depends on the ability of the cameras to calculate the 2-D centroid of markers on the camera retina and the ability of the software to reconstruct the 3-D marker position from its 2-D centroids from the retinas of each of the cameras in use in which the marker is visible. Cameras with high resolution and grayscale image recording capabilities are now available on the market. However, quantification and evidence on the effect of upgrading a motion analysis system on outcome measurements have not been reported as yet. Here, we report an assessment of the effect on gait kinematic data of two motion capture systems, an older version (Vicon 612 with 8 cameras) and an upgraded version (Vicon MX-Giganet with 12 cameras) manufactured by Oxford metrics Ltd., UK.

METHODS

Ten able-bodied male subjects (age 25.1 ± 3.9 years, height 1.77 ± 0.05 m, mass 77 ± 9.96 kg) participated in this study. Approval for the study was obtained from the Bioengineering Unit Departmental Ethics Committee prior to tests commencing.

An eight-camera motion capture system (Vicon 612, Oxford Metrics Ltd., UK) and its upgraded version a twelve-camera motion analysis system (Vicon MX-Giganet, Oxford Metrics Ltd., UK) were operated in parallel. For the eight cameras system, each camera (Vicon V-series, MCam, Oxford Metrics Ltd., UK) had a resolution of 1000 x 1000 pixels. Cameras positions, on adjustable tripods, were kept consistent between laboratory sessions to create a capture volume with sides of approximately 4 m in length. The MX-Giganet system was connected to six T160 (16 Megapixel) and six T40 (4 Megapixel) cameras (Vicon, Oxford Metrics Ltd., UK) placed in fixed positions on a rail around the laboratory walls. T160 and T40 camera have a resolution of 4704 x 3456 pixels and 2353 x 1728 pixels respectively. The capture volume had sides of length of 6 m approximately. The two systems were calibrated prior to each test session with calibration tools as suggested by the supplier. Data sampling was set at 120 Hz and 100 Hz for the old and new motion systems respectively.

A marker set comprising of 5 clusters, with four 14 mm diameter markers each, attached to the lower limbs and pelvis, and three individual markers on each foot was used during dynamic data capture. Each test session commenced with the capture of nine static anatomical landmark calibration trials using a pointer [1]. Malleoli were calibrated by attaching markers directly on them. Hip joint centre was estimated through regression equations [2], knee and ankle joint centres as mid point between epicondyles and malleoli respectively. Anatomical frames of reference were constructed following standard recommendations [3, 4]. Kinematic data were calculated using the joint coordinate system convention [5].

Three walking trials were captured simultaneously with both systems while the subjects walked at their own natural speed wearing shoes. Comparisons between kinematic outputs, as obtained from the data captured by both systems, were conducted. Paired *t*-tests, at 0.05 level of significance, were used to determine differences in kinematic data between the two systems, assuming all data processing carried was identical.

Reconstruction residuals were used to assess the accuracy of the 3-D reconstruction of markers position. The reconstruction residual was defined as the average error distance, calculated by the photogrammetric system, which prevents all camera measurement rays from meeting at an identical point in space [6]. The smaller the average residual is, the more accurate the location of the marker. Residuals of each marker obtained from both systems were compared for static and dynamic trials. In particular, the averages of the residuals of each marker across all subjects were kept for the analysis.

RESULTS AND DISCUSSION

When processing the trial data, a more careful reconstruction and markers 'snagging' procedure was required by the user for data capture with Vicon 612 to limit the presence of erratic markers trajectories and avoid gaps due to missed markers.

Residuals were smaller when using the MX-Giganet system for both static and dynamic trials. Average residuals were confined to 1 mm for MX-Giganet system and 3 mm for Vicon 612. Static residuals were generally smaller than dynamic. The reduced residuals in the MX-Giganet system are likely due to the high performing specifications of the T-series cameras. The higher resolution and the grayscale marker fitting allow markers to be seen from greater distance and more precisely, reducing also the presence of ghosting and marker merging. Moreover, the superior number of cameras, 12 T-series against 8 MCam, increased the likelihood of one marker being seen simultaneously by more than two cameras thus increasing accuracy of reconstruction.

Very good agreement in kinematic outcomes was observed between motion capture systems. At the bottom of each plot *p*-values are graphed on a point-by-point basis. Differences between systems, in the group average trace, to a maximum of 3° were observed, but they were not significant (*p*-value >0.05).

Since anatomical frame position and orientation is derived from captured markers coordinates in each sampled instant of time, differences in the coordinates of markers detected by the two camera types directly affect kinematic outputs as shown in the study results. Kinematic outputs are therefore system dependent.

CONCLUSIONS

Vicon MX-Giganet with T-series cameras may be considered the new state-of-art of motion analysis capturing systems. Given the increased camera resolution and grayscale fitting, this system is capable of producing highly accurate reconstruction of markers. This limits the instrumentation error component in outcome measurements when compared to earlier capturing systems. Thus, upgrading our laboratory data capture equipment allowed for a greater accuracy in the kinematic outputs.

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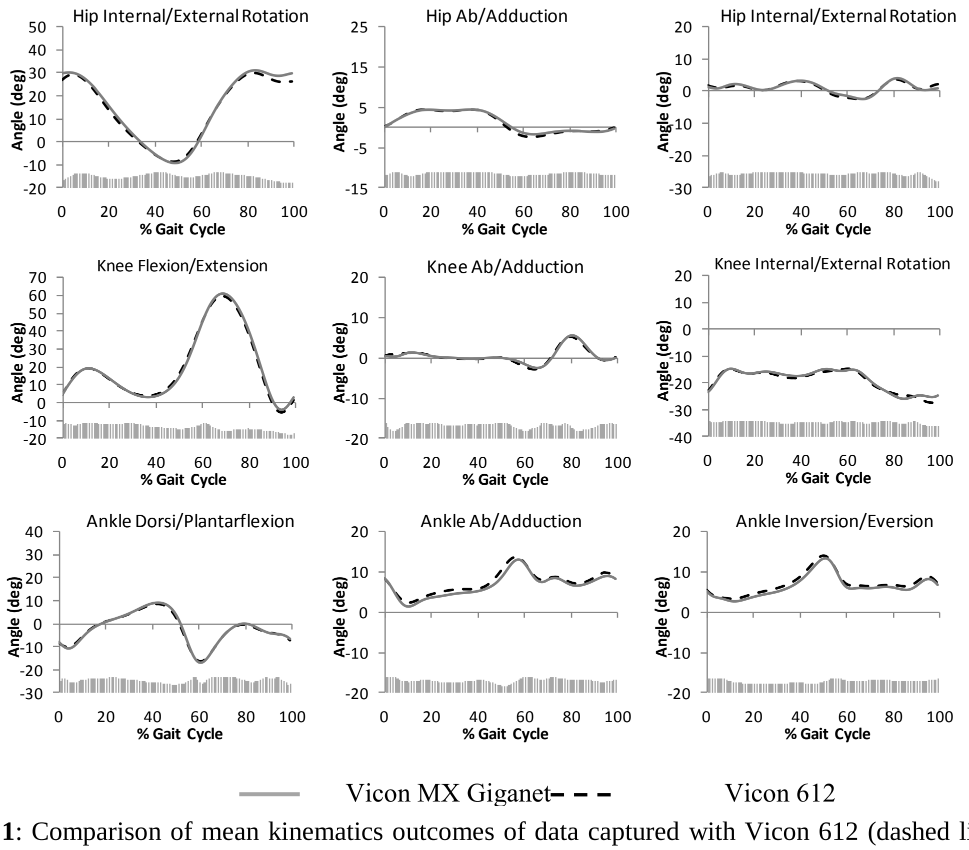

Figure 1: Comparison of mean kinematics outcomes of data captured with Vicon 612 (dashed line) and Vicon MX Giganet (grey solid line). *P*-values throughout the gait cycle are reported at the bottom as grey bars.