Posturographic Analysis Is Possible Without Ground Reaction Forces Measurement Through Markerless Motion Capture

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INTRODUCTION

Posturographic analysis is a commonly used non-invasive clinical assessment technique which quantifies the central nervous system control of posture and balance. The movement of the center of mass (COM) movement in antero-posterior and medio-lateral directions while standing still for a fixed time has been used to identify neurological pathology. However, direct measurement of the trajectory of the COM has not been practical since it requires measuring the COM of each body segment and summing their weighted contribution to the overall COM. Thus, the most common and widespread alternative is to measure the center of pressure (COP) by means of a force plate and then performing a double integration to obtain the COM [Zatsiorsky and King, 1998]. [Morasso, 1999]

The purpose of this work was to develop and validate a simple inexpensive fully automatic, three dimensional video based approach to measure the postural movement of the COM without the need of a force plate. A 3D markerless motion capture (MMC) method was implemented to measure the COM and calculate the COP from the direct measurement of the center of the body volume of the subject.

METHODS

The MMC system utilized in the study was equipped with 8 (Basler) VGA cameras. The MMC method used was the one described in [Corazza, 2006] and provided for every captured frame a 3D representation (visual hull, 1 cm voxel size) of the subject which is an approximation of the body outer surface and inner volume. Thus, the calculation of the center of the body volume, and under the assumption of homogeneous density the center of mass, is straightforward. From the projection of the COM on the ground plane (vector $\mathbf{u}_{COM}$ in (1)) it is possible, under the quasi-static motion and small angles θ (see Figure 1) assumptions, to calculate the COP by solving equation (1), where k_s is a shape factor that we can calculate from MMC data.

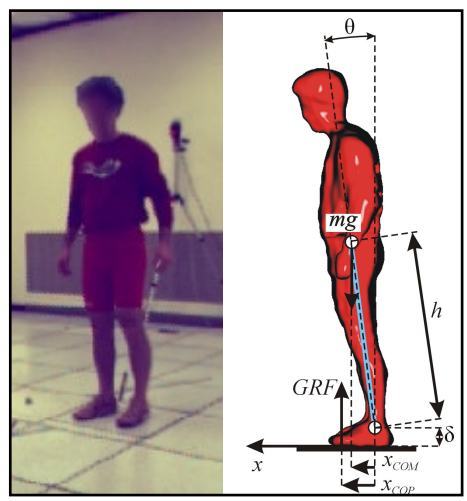

Figure 1: Left: video frame of a subject from one of the 8 (Basler) VGA cameras of the MMC system. Right: visual hull of the subject in the same frame, with in evidence the center of mass and the ankle joint center; the analysis was 3D, sagittal view is shown.

$$\mathbf{u}_{COP} = \mathbf{u}_{COM} - \frac{(hk_s + \delta)}{g}\ddot{\mathbf{u}}_{COM} \qquad (1)$$

To properly perform the derivation of the COM trajectory a Kalman filter and a B-

spline fitting method were used at every derivation step. Using the same equation it was also possible to calculate the COM from the measurement of the COP obtained from a force plate. To validate our new method a comparison over 3 subjects (3 trials each) was performed between i) the calculated MMC COP and the measured COP from the force plate, ii) the measured MMC COM and the calculated COM from the force plate data. All calculations were performed under the same assumptions described in [Morasso, 1999]. Differently from recent studies [Goffredo, 2006] the method is fully automatic, three dimensional, generates subject specific models and was validated against force plate data for both COM and COP.

RESULTS AND DISCUSSION

The mean absolute deviations for the COM between the two methods were 1.0 mm (0.7) mm) and 1.2 mm (1.0 mm) in the antero-posterior and medio-lateral directions, respectively.

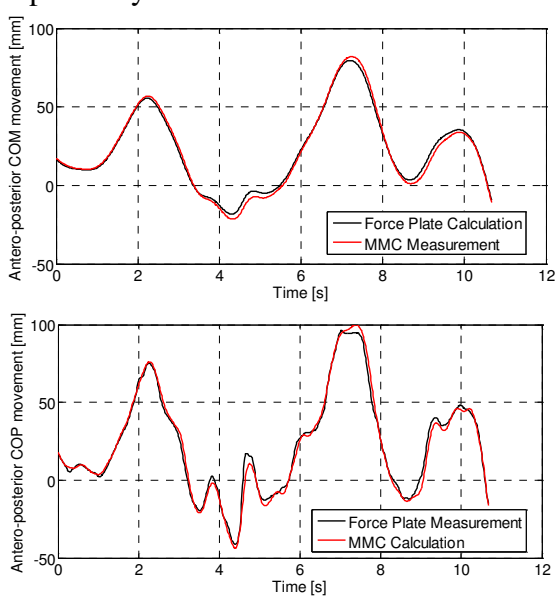

Figure 2: COM (top) and COP (bottom) trajectories along the antero-posterior axis as obtained from the force plate (black) or the MMC method (red).

For the COP they were 1.9 mm (2.3 mm) and 1.4 mm (2.2 mm). Figure 2 shows how the two set of results coming from MMC and force plate line up almost perfectly. By tracking the captured sequences it is possible to locate the ankle joint and segment the foot from the rest of the body, thus excluding it from the calculations in the (1) accordingly to the postural biomechanical model assumptions [Morasso, 1999]. Nevertheless very similar results were obtained either including or excluding the mass of the foot from the calculations, making the tracking process unnecessary and thus the implementation of the method even simpler and faster.

SUMMARY/CONCLUSIONS

A novel method was presented which allows the accurate measurement of COM and COP using only kinematic data through MMC method and without the need of a force plate or pressure mat. The method operates directly on visual hulls and thus does not even require the tracking of the subject through the captured sequence nor the previous definition of a model for it. Effectiveness and accuracy of the method was demonstrated, showing its efficacy and ease of use for clinical applications.

REFERENCES

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