Inertial compensation in moving force plates

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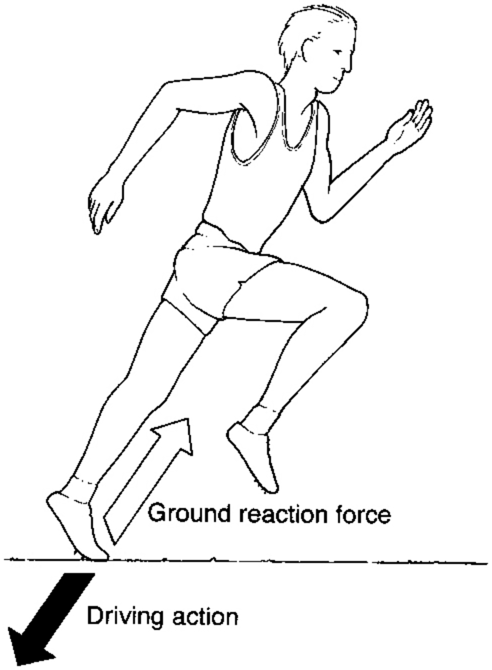
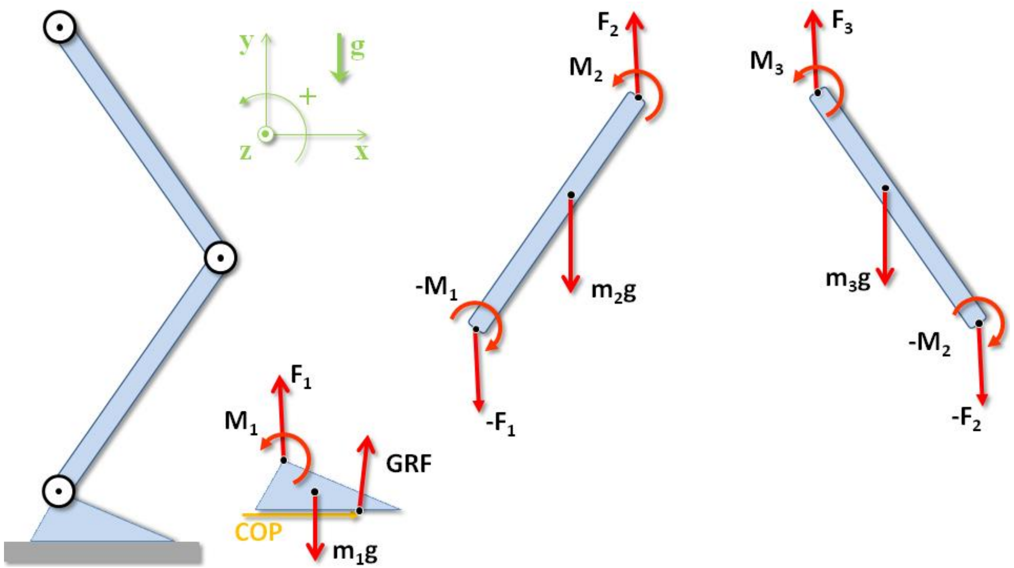
BACKGROUND

Instrumented Treadmills

- load cells measure 3D ground reaction forces under each foot
- allows for a more convenient environment for inverse dynamic gait analysis





Background

Instrumented Treadmills

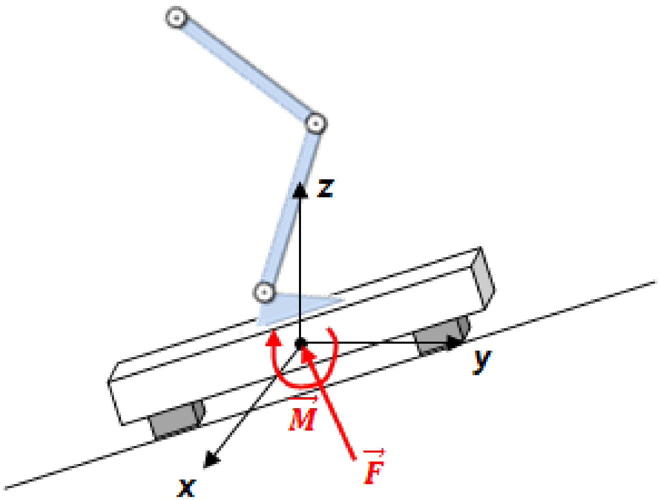
- recent treadmills are capable of translating and rotating the walking surface
- able to study changes in gait due to perturbations
- moving the treadmill platform causes inertial artifacts in the ground reaction forces
- a compensation method is necessary to reduce these errors

METHODS

Mathematical Model for Inertial Artifacts

- 3D force and moments generated by inertia and gravity are linearly related to accelerometer signals

    -accelerometers are capable of detecting inertial effects



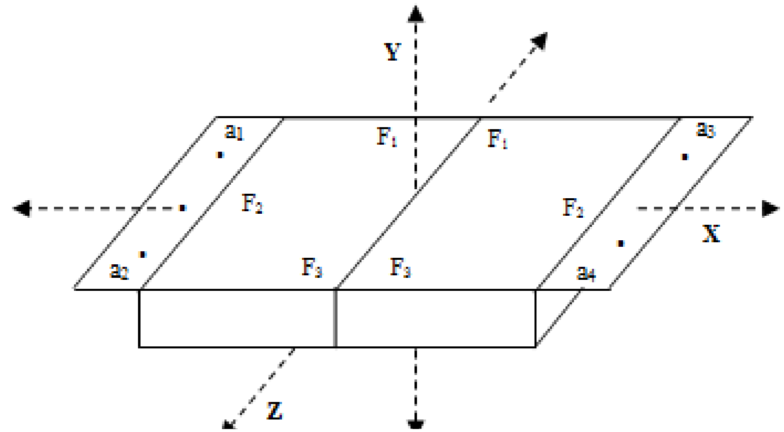
$$\begin{bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{bmatrix} = \boldsymbol{C}_{6\times13} \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \\ \vdots \\ s_{12} \\ 1 \end{bmatrix} \Rightarrow \boldsymbol{G} = \boldsymbol{C} \cdot \boldsymbol{s}$$

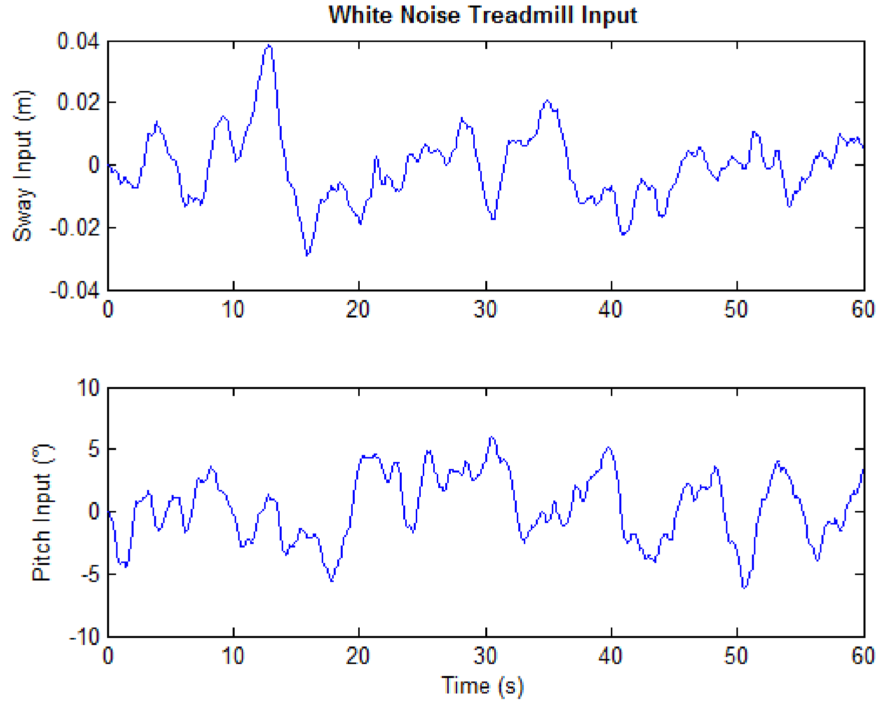
- coefficient matrix ***C*** contains mass properties

METHODS

Instrumentation

- 2 DOF platform motion
  - -mediolateral translation
  - -sagittal pitch
- 4 triaxial accelerometers mounted on the corners of the rigid treadmill platform
- random signals used to move treadmill
  - -forces and accelerations are recorded





METHODS

Procedure

1 C estimated from accelerometer signals and inertial effects from a 60 second, unloaded calibration trial with random movement

$$\boldsymbol{C} = argmin_C \sum_i ||\boldsymbol{G}_i - \boldsymbol{C} \cdot \boldsymbol{s}_i||^2$$

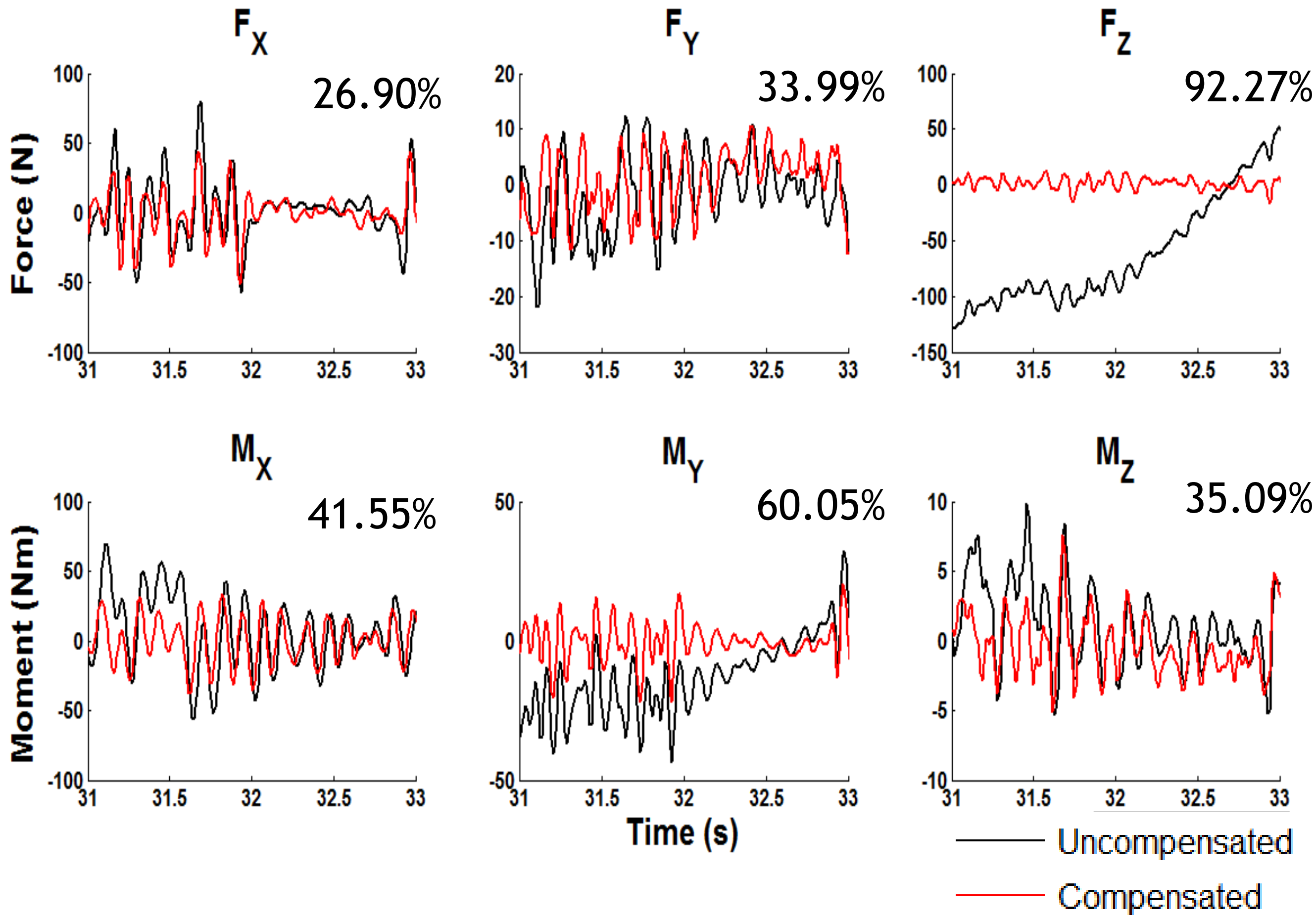
2 Record force and acceleration from a separate 60 second unloaded trial with different random movements

3 Use the mass coefficients from the calibration trial to compensate for inertial effects

$$\boldsymbol{G}_{corrected} = \boldsymbol{G} - \boldsymbol{C} \cdot \boldsymbol{s}$$

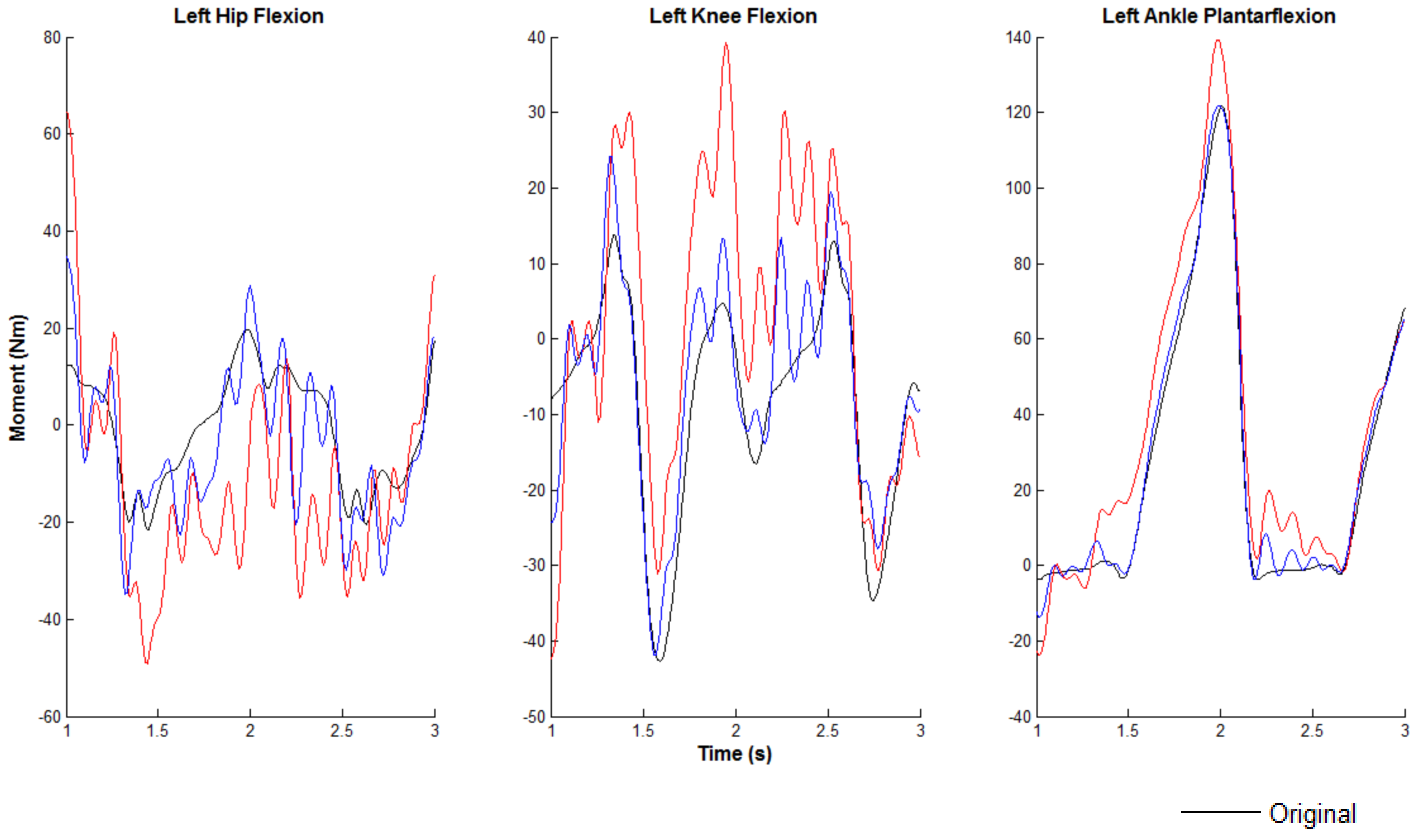
Results

- average reduction of 76.76% and 45.61% in the RMS of force and moment signals



RESULTS

Sensitivity of Joint Moment Calculations



Discussion

Limitations

- assumption of an ideal rigid body
- accelerometer sensitivity
- influenced by the cutoff frequency of the low-pass filter
- not limited to 2-DOF systems only

Recommendations

- obtain calibration coefficients from similar treadmill movements
- perform a coordinate transformation to register new force data in the non-moving global reference frame

CONCLUSIONS

- preliminary results are capable of reducing inertial errors to a more acceptable level
- the linear accelerometer-based method is simple and easy to implement
- can be used for any application with a moving force plate

Thank you!

Supplemental

$$\overrightarrow{F'} = m\overrightarrow{a'} - m\overrightarrow{Rg}$$

$$\overrightarrow{M'} = I\overrightarrow{\omega'} + (\overrightarrow{\omega'} \cdot I\overrightarrow{\omega'})$$

$$\vec{s} = R(\vec{a}_o - \vec{g}) + (\vec{\omega} \times \vec{r}) + \vec{\omega} \times (\vec{\omega} \times \vec{r})$$