

METHODS

Two changes were made to produce a new MOS equation. First, to avoid having to measure or approximate the ground reaction force (GRF), the equation is developed using x_{COP} as the origin, so that the GRF produces no effective moment in that frame of reference. Also, to simplify derivation, the new equation is carried out using a new variable to represent the movement of x_{COM} relative to x_{COP} , $\Delta x(t) = x_{COP} - x_{COM}$. Following a derivation similar to the original produced:

$$MOS_{new}(t) = x_{COP}(t) - \left(x_{COM}(t) - \frac{(v_{COP}(t) - v_{COM}(t))}{\omega_0} \right) \quad (2)$$

Therefore, larger differences between v_{COM} and v_{COP} will increase MOS, and a proportionally smaller distance between the COP and COM will be needed to keep MOS positive (stable). If x_{COP} is assumed to be constant, this equation becomes identical to equation (1). However, changes in both COM and COP positions and velocities can now be addressed.

To illustrate some of the effects of including v_{COP} in the MOS, sample gait data from one child with normal walking gait (male, 11.6 years) and one with gait impaired by cerebral palsy (CP) (male, 11.3 years) was obtained from a protocol approved by the Institutional Review Board at the National Institutes of Health in Bethesda, MD. Spatiotemporal and kinematic data were collected using a 10-camera motion capture system (Vicon, USA) and a custom gait model and analyzed using Visual3D software (C-Motion, USA). COP was recorded using three walkway force plates (AMTI, USA). $x_{COP_{max}}$ is approximated as the position of a lateral foot marker on top of each forefoot. Integration and data analysis for two steps averaged for each side were performed using MATLAB (MathWorks, USA).

RESULTS AND DISCUSSION

Although no definitive clinical conclusions can be presented here, several general trends do stand out (Figure 2). First, all MOS measures were generally lower for the healthy individual and $MOS_{act(orig)}$ was usually well below the MOS_{max} throughout SLS, whereas the patient used most or all of their available MOS reserve ($MOS_{max} - MOS_{act}$) throughout single-limb stance (SLS), indicating a more protective form of walking gait. However, because MOS_{max} uses an approximated $x_{COP_{max}}$ and $MOS_{act(orig)}$ does not use v_{COP} , MOS comparisons are not entirely consistent, demonstrating the need for accurate COP and $x_{COP_{max}}$ measurements (as is possible with a pressure sensor map) to properly calculate MOS_{act} and MOS_{max} .

This comparison also reveals a more dynamic $MOS_{act(new)}$ as compared to $MOS_{act(orig)}$. By incorporating actual v_{COP} and accounting for its translation velocity, the true variability of the actual MOS is revealed. This temporal sensitivity is

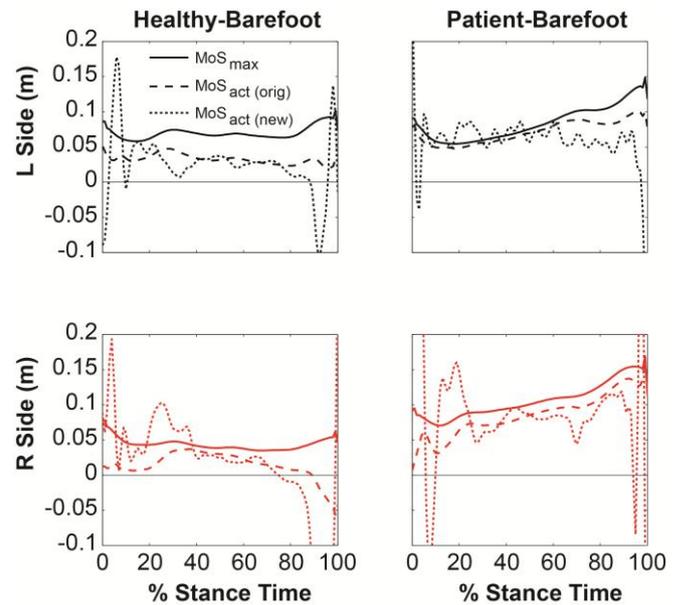


Figure 2: Comparisons of $MOS_{max(orig)}$, $MOS_{act(orig)}$, and $MOS_{act(new)}$ for normal and CP-affected walking gait.

likely to be more useful in detecting the occurrences of minimum or even negative MOS, which will indicate the greatest fall susceptibility. This type of information could be useful in detecting potential gait instabilities that are not detected by exclusive examination of MOS_{max} and MOS_{orig} .

CONCLUSION

Past walking studies that used the MOS [2, 3, 4] may be incomplete due to their sole focus on MOS_{max} and limited by an MOS equation that oversimplifies walking stability by excluding actual v_{COP} . Furthermore, assuming the maximal COP location at a fixed location on the foot fails to acknowledge that the true location of $x_{COP_{max}}$ on the foot varies throughout the stance phase during walking. A new MOS equation has been developed for SLS that includes v_{COP} while maintaining the original MOS features of simplicity, kinematic and kinetic representation, and instantaneous measurement that many other stability metrics lack. However, the true usefulness of this adapted metric can only be fully assessed using a thorough evaluation of walking data for individuals with normal and limited stability that includes accurate measurements of x_{COM} , $x_{COP_{max}}$, and $x_{COP_{act}}$.

ACKNOWLEDGEMENTS

The work presented here was funded in part by the intramural research program at the NIH Clinical Center.

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