Locomotor Stability with Upper Limb Absence: A Momentum Analysis

[1] Jenny A Kent, [1,2] Matthew J Major

[1] Northwestern University Dept. of Physical Medicine & Rehabilitation, Chicago, IL [2] Jesse Brown VA Medical Center, USA Chicago, IL

email: jenny.kent@northwestern.edu, web: http://www.nupoc.northwestern.edu/

Introduction

- There is a high fall rate in individuals with upper limb absence (ULA) [1].
- This may be related to the **physical imbalance** resulting from the loss of part of one arm.
- In an individual without ULA, the angular (rotational) momenta of the parts of the body cancel out during walking such that **whole-body angular momentum (*L*) remains close to zero**, promoting stability.
- This **balance will be affected by unilateral loss of mass** due to ULA, increasing *L*, **which may increase fall risk**.
- Individuals with ULA **swing their sound arm more** [2], which may compound this problem (Figure 1).

AIM: To characterize the *whole body angular momentum, L,* of persons with ULA walking with and without a mock prosthesis designed to mimic the length, mass and inertial properties of the sound arm.

Hypothesis 1: Unilateral ULA leads to **asymmetries** in *L*.

Hypothesis 2: Asymmetries will **persist or worsen when a prosthesis is worn**, as arm swing remains asymmetrical [2]

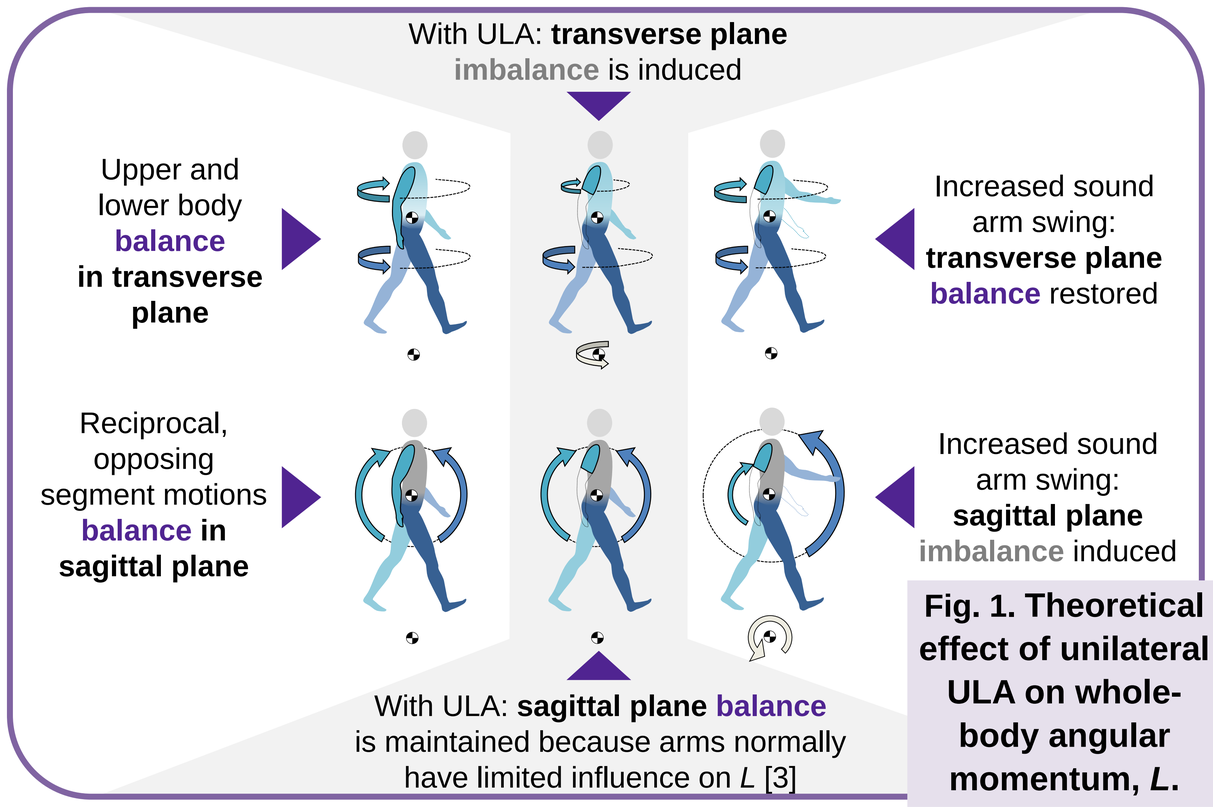
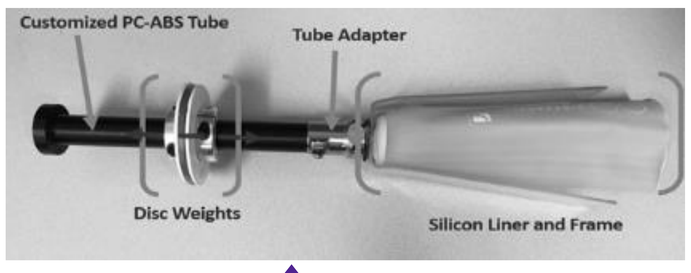


Fig. 1. Theoretical effect of unilateral ULA on whole-body angular momentum, *L*.

Methods



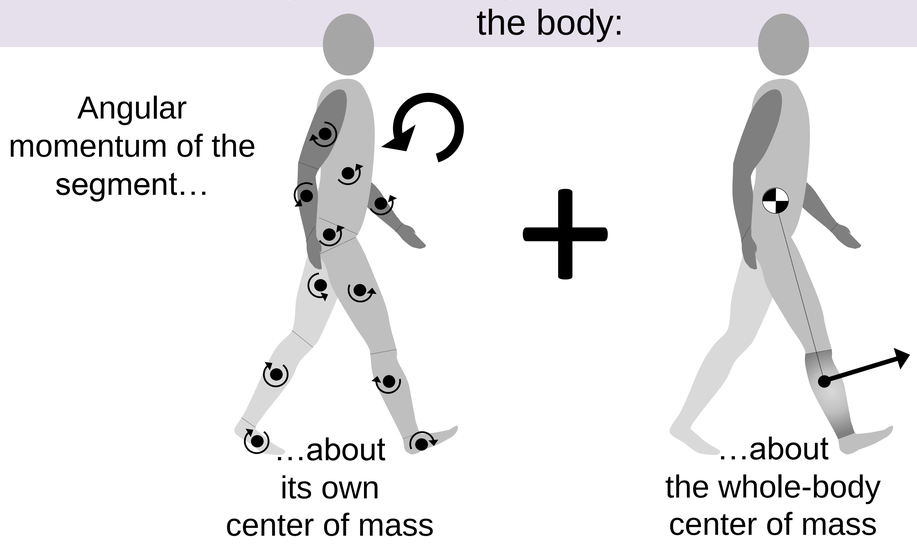
PARTICIPANTS
Ten individuals with unilateral ULA (7 transradial, 3 transhumeral; 7M/3F; 48.9±18.9 yrs, 75.3±18.6 kg, 1.75±0.08 m).

Fig. 2. Mock prosthesis. Mass and inertial properties matched to sound side [2].

- **Kinematic data** from a full-body marker set were collected at 120 Hz using a digital motion capture system (Motion Analysis Corp, CA).
- Subjects walked at a self-selected pace wearing **1) no prosthesis**, and **2) a mock prosthesis** (Figure 2); order randomized.
- For each condition, *L* was computed for ten strides in the sagittal, coronal and transverse planes (Figure 3).
- Values were normalized to height, body mass and walking speed.
- *L* range was computed in the first 50% of the gait cycle ($\boldsymbol{L_{50}}$) bilaterally, and over the whole gait cycle ($\boldsymbol{L_{100}}$) for the affected side.
- Two-way repeated measures ANOVAs were used to assess the effects of side and prosthesis condition on L_{50}.
- Paired t-tests were used to determine the effect of prosthesis condition on L_{100} (α=0.05).

Fig. 3. WHOLE BODY ANGULAR MOMENTUM, *L*

Sum of two components of angular momentum for all segments of the body:



Results

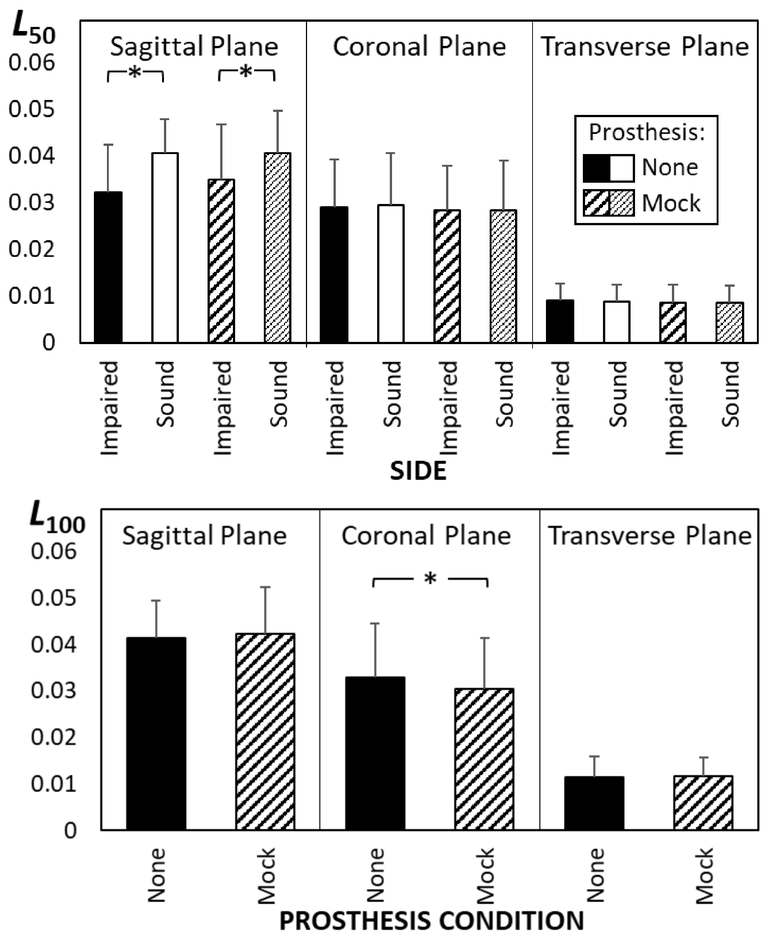


Fig. 4. Whole-body angular momentum range over the first 50% gait cycle, L_{50}.
*sig. at 0.05.

L range was significantly higher during the sound side step in the sagittal plane (Figure 4).

Fig. 5. Whole-body angular momentum range over the whole gait cycle, L_{100}.
*sig. at 0.05.

L range was significantly higher lower in the coronal plane when wearing the mock prosthesis (Figure 5).

- Results suggest that the **loss of mass on the affected side may be compensated for by an increase in the velocity of the sound arm**, which restores a balance about the vertical axis.
- However, there is a **higher *L* range on the sound side in the sagittal plane** in comparison to the impaired side**.**
- Use of a **prosthesis reduces coronal plane *L***, potentially enhancing medial-lateral stability.
- **Use of a prosthesis does not reduce the sagittal plane imbalance.**

Conclusions

- There may be a **greater risk of loss of balance in people with ULA** following a perturbation such as a trip, particularly when it occurs during the stance phase of the sound side during which ***L* is elevated**.
- Individuals with ULA may experience greater risk of falls due to a unique vulnerability to perturbations related to an **angular momentum imbalance**.

References

[1] Major, M.J., 2018. Phys. Ther. 99, 377-387.
[2] Major, M.J., et al, 2019. J. Electromyogr. Kinesiol. 48, 145-151.
[3] Herr, H. & Popovic, M., 2008. J. Exp. Biol. 211, 467-481.

Acknowledgements

We would thank John Brinkmann, CPO, for his assistance with designing the mock prosthesis, and Suzanne McConn, MS, and Rebecca Stine, MS, for their assistance with data collection. This work was supported by the United States Department of Veterans Affairs Rehabilitation Research and Development Service (#1IK2RX001322 and #1I21RX001388).