# When Are We Least Stable During Walking?

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## Background

- Loss of stability and falls are a major public health concern
  - US workplace falls cost $8.6 billion in 2010 [1]
  - 25% of adults > 65 years old fall each year [2]
- Wearable robots can help address balance problems:
  - Point in gait cycle when people are least stable is unknown
- Compromised balance is indicated and measured by:
  - Increased dynamic stability margin [3]
  - Increased step width [4]
  - Decreased step length [4]

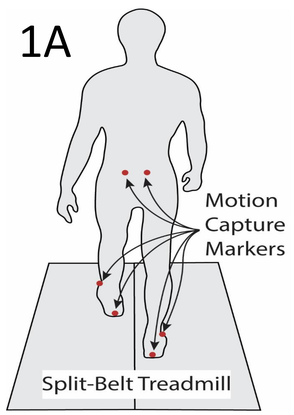
## Hypothesis

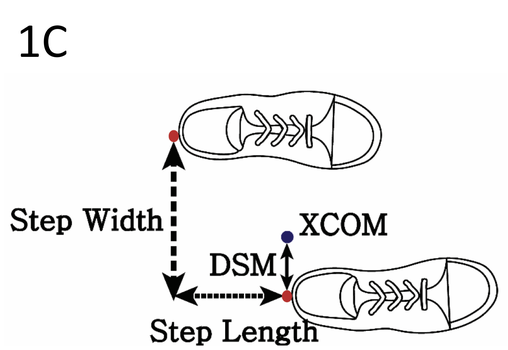
**People are least stable to forward slips between 15 and 20% of the gait cycle**

## Methods

- 10 subjects walked on a split-belt treadmill (Fig 1A)
- Belt slips were applied 10x to each leg at 6 times
  - 10, 15, 20, 30, 40, and 50% gait cycle (Fig 1B)
- Balance metrics were calculated from motion capture (Fig 1C)

**Slip Examples**



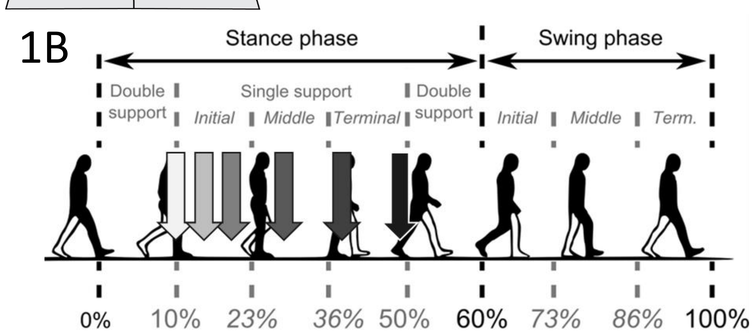




**Figure 1A –** Experimental setup, **Figure 1B** – Slip timings during the gait cycle, **Figure 1C** – Stability metrics

## Results

- "*" in Fig 2 represents that slip timing had a significant effect on that step
- Bars in Fig 2 represent two timings were significantly different
- "L" represents value is normalized to leg length

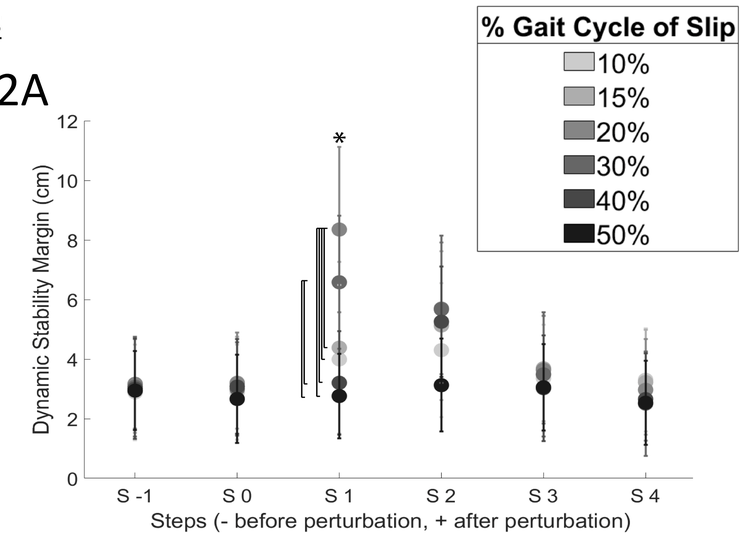
Dynamic Stability Margin (Fig 2A)
- Larger during first step after 20 and 30% slips

Step Width (Fig 2B)
- Larger during second and third steps after 20% slips

Step Length (Fig 2C)
- Lower during second step after 20 and 30% slips

Foot Placement (Fig 2D)
- Most different for second step after 30% slips

2A




2B




2C




2D




## Key Take-Away Points

1. People are least stable to forward slips between 20-30% of the gait cycle
2. Slips at 20% influence width more than length of foot placement
3. Slips at 30% influence length more than width of foot placement

## References

**[1]** H.R. Marucci-Wellman, et al. *J. Saf. Res.*, 2015 **[2]** G. Bergen, et al. *MMWR*, 2016 **[3]** A. L. Hof, et al. *J. Exp. Biol.*, 2010 **[4]** J. C. Dean, et al. *IEEE Trans. Biomed. Eng.*, 2007