Dynamic Stability of Walking During Anterior-Posterior and Medio-Lateral Support Surface and Visual Field Translations

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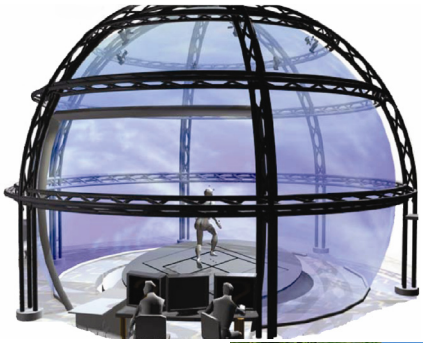
INTRODUCTION

- Quantifying responses to de-stabilizing events is critical for assessing effectiveness of gait and balance training interventions
- In robotics, Floquet multipliers (FM) are used to quantify walking stability [1]
- Healthy elderly exhibit greater FM than young subjects during unperturbed walking [2]
- Dynamic walking model predicts FM's do not increase with larger perturbations [3]
- ***How do continuous pseudo-random horizontal oscillations of the walking surface and visual field affect gait stability?***

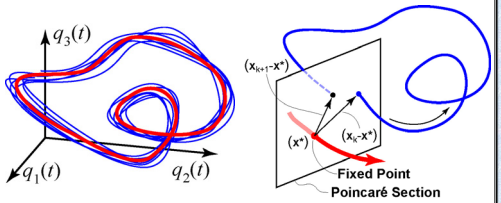
METHODS

- 12 Healthy subjects, Ages 18-45
- Five 3-min treadmill walking trials in the Computer Assisted Rehabilitation ENvironment (CAREN) at the Center for the Intrepid (CFI)



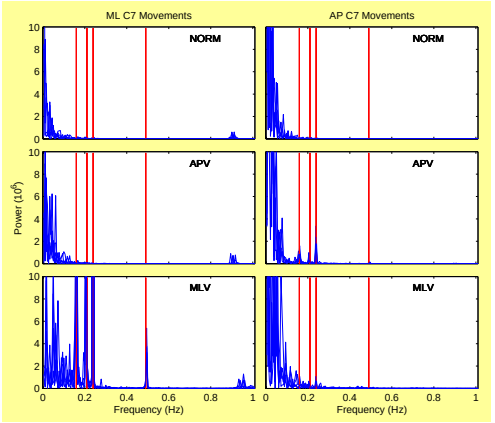
- Immersive virtual reality scene providing speed appropriate optic flow

- Five conditions:
  - NORM: No perturbation
  - APP: Anterior-posterior platform
  - APV: Anterior-posterior visual
  - MLP: Medio-lateral platform
  - MLV: Medio-lateral visual
- Perturbations applied as sum of sines with frequencies of 0.16, 0.21, 0.24, 0.49 Hz.
- Collected kinematic data for head, trunk, pelvis & feet using Vicon (Oxford Metrics, Oxford, UK)
- Power spectral analyses performed to determine strength of coupling between perturbations and subject movements
- Floquet multipliers (FM) used to quantify orbital stability using the C7 vertebral marker

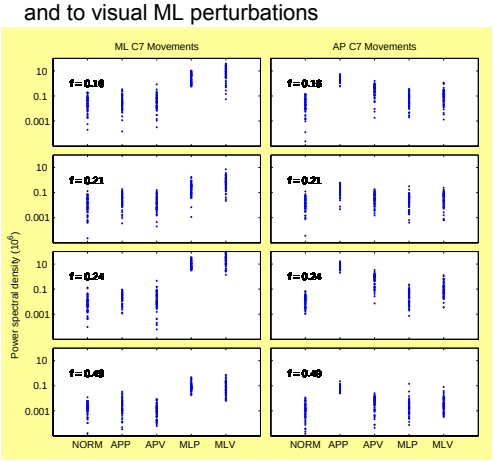


SPECTRAL ANALYSIS

- **Hyp. #1:** Applied perturbations will significantly affect subjects' kinematics
- C7 movements had significantly increased spectral power at all input frequencies

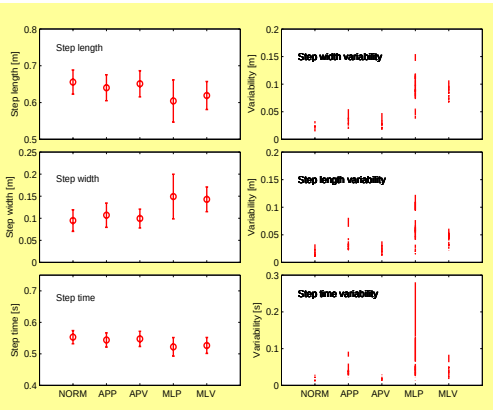


- Greater responses to AP platform perturbations and to visual ML perturbations



GAIT KINEMATICS

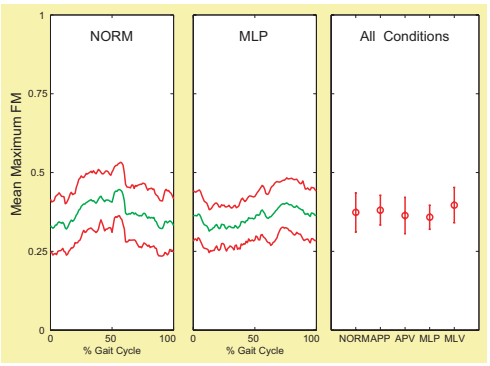
- **Hyp. #2:** Greater variability will be observed during perturbed walking



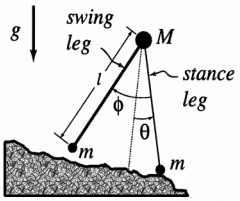
- Minimal effects of AP perturbations
- During ML perturbations:
  - Significantly shorter step lengths (SL)
  - Significantly wider step widths (SW)
  - Significantly more variable SL's and SW's

ORBITAL STABILITY

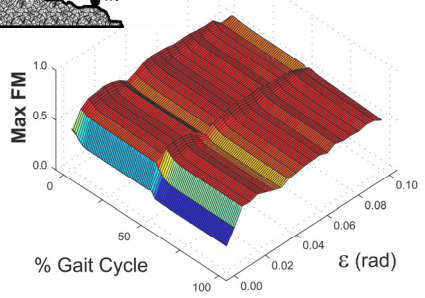
- **Hyp. #3:** Subjects will have less gait stability during ML and AP platform and visual field perturbations than during unperturbed walking
- No subjects fell during this study
- Subjects felt most and least stable during APV and MLV conditions, respectively
- Subjects stable (FM < 1) for all conditions
- No significant differences in average Maximum FM between conditions:



- Results confirm previous dynamic walking model predictions that greater environmental variability does not imply greater instability [3]:



- Passive model walks down "bumpy" slope
- ε defines avg. size of "bumps" on the slope



CONCLUSIONS

- Perturbations significantly affected kinematics
- ML visual and platform perturbations were associated with shorter and wider steps
- Even with substantial perturbations, subjects maintained orbital gait stability
- Results confirm predictions that greater variability does not imply greater instability [3]
- FM may not predict *risk* of falling

REFERENCES

1. Hurmuzlu, Y. et al. (2004). *Automatica*,40(10): 1647-1664.
2. Kang, H.G. and Dingwell, J.B., (2008). *J Biomech.*, In Review.
3. Su, J.L. and Dingwell, J.B., (2007). *J Biomech Eng.*, 129:802-810.

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