

# The role of arm swing in stabilizing human walking

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## SUMMARY

We investigated the effect of arm swing on stability in human walking using perturbation experiments. Decay after a perturbation towards the normal walking pattern was quantified using an exponential function, and it was found that even during small perturbations the arms have a role in stabilizing gait.

## INTRODUCTION

It is generally believed that arm swing is an essential part of human walking, and it has been shown that walking without natural arm swing increases metabolic costs of walking [1], either due to the fact that the bigger transverse momentum that needs to be counteracted [2], or due to the larger vertical COM movements.. Moreover, there are several claims that arm swing during human locomotion increases stability of bipedal walking [1], although this has never been directly tested. In the current study, we tested the role of arm swing in human gait using perturbation experiments.

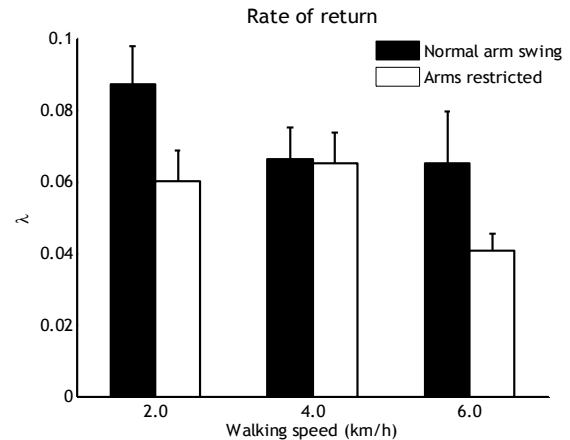
## METHODS

6 healthy male subjects walked on a treadmill at three different speeds, at each speed, they walked five minutes with normal arm swing and with arm swing restricted by a belt at pelvis height (steady-state trials). Moreover, the same 6 conditions were done with forward perturbations (a pull to the shoulders in the direction of walking, with a force of about 200N and a duration of 200ms) occurring unexpectedly (perturbation trials). During the entire experiment, trunk 3d kinematics were recorded using an Ototrak system. The X axis was designated as forward, Y axis to the left, and Z axis upward.

The steady-state trials were used for the construction of an average 'limit cycle' (with state variables forward and upward linear velocity, and rotation around X and Z axes), to which the perturbation trials were related. Euclidean distances between the gaitcycles during the perturbation trials and the 'limit cycle' were then calculated, and the exponential decay towards the 'limit cycle' after a perturbation was quantified using:

$$D(t) = a + b * e^{-\lambda t}$$

where D referred to the Euclidian distance between the perturbed gait cycle and 'limit cycle', 'a' refers to the relaxation distance, 'b' refers to the size of the initial



**Figure 1:** The effects of arm swing and walking speed on  $\lambda$ . Error bars represent standard errors.

perturbation,  $\lambda$  refers to the rate of return towards the limit cycle and  $t$  is time normalized to mean stride time. Higher values of  $\lambda$  indicate more stable gait patterns. Individual median  $\lambda$  per condition were determined, and the effects of walking speed and arm swing on  $\lambda$  were tested using a 3 X 2 repeated measures ANOVA.

## RESULTS AND DISCUSSION

In general, the decay towards the limit cycle occurred within one full gait cycle. Trials with restricted arm swing showed a lower  $\lambda$  than trials with normal arm swing ( $P=0.032$ ), indicating more stable gait patterns with normal arm swing. Moreover, values of  $\lambda$  decreased with increasing walking speed ( $P=0.024$ )

These results indicate that the arms contribute to stability in normal human walking. Interestingly, these effects could be found using rather small perturbations, which tended to decay within one gait cycle. This latter fact may either indicate that the contribution of the arms on stability in human walking is rather large, or that the measure used in the current study has a high sensitivity to changes in stability.

## REFERENCES

- 1 Ortega, J.D., et al., J Biomech, **41**, 3303-3308, 2008.
- 2 Bruijn, S.M., et al., Gait Posture, **27**, 455-462, 2008.

## ACKNOWLEDGEMENTS

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