The Effect of Step Height Disturbance on Step

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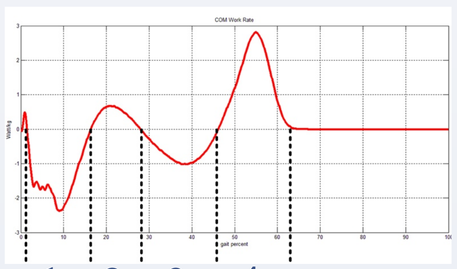
Motivation

In this study we addressed the problem of how humans adapt their gait when they encounter a step height disturbance. The changes in step to step transitions of human gait might help us to explain how humans control their walking when such a disturbance is encountered.

Background

Step to Step Transitions of Human Walking[1]:



1 2 3 4

- Center of Mass Work Rate: $\sum F.v_{COM}$

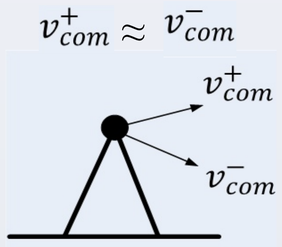
1) Collision 3) Pre-Load

2) Rebound 4) Push Off

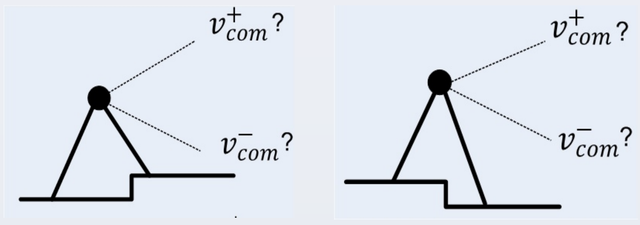
- No net mechanical energy is consumed in over ground walking.

Optimal Gait: Push Off ≈ Collision

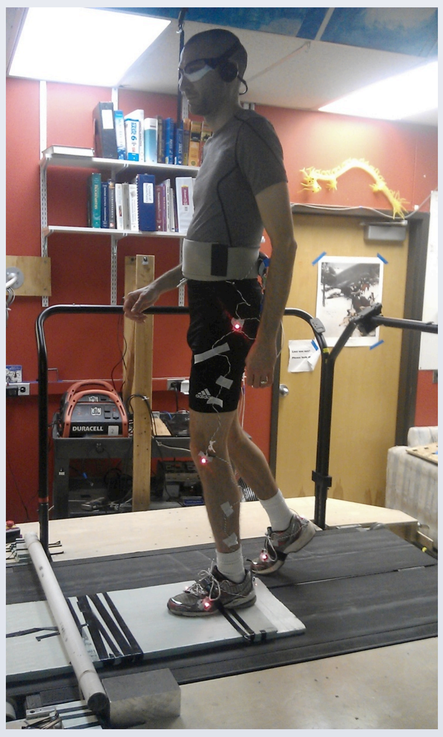
$v_{com}^{+} \approx v_{com}^{-}$

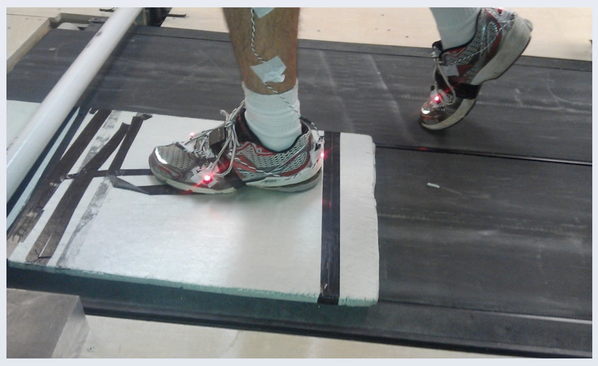


When the disturbance is applied: Push Off ? Collision

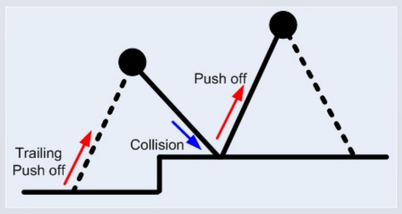


Methods

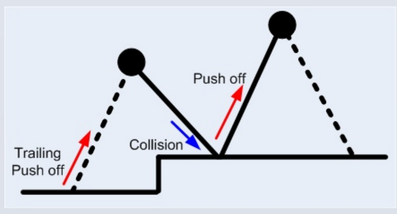




- Treadmill tests were performed on 3 test subjects with a walking speed of 1.25 m/s.
- Foams which have 3 cm width and 1.8 m length were put under the test subject's both feet.
- Two different test cases were applied: in the first test case test subject's **eyes were open** and they were able to see the foams coming under their feet. In the second case test subject's **eyes were closed**, so they could not have an opportunity to adjust themselves before they stepped on foams.



Step on foam

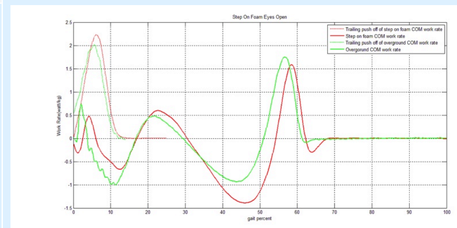
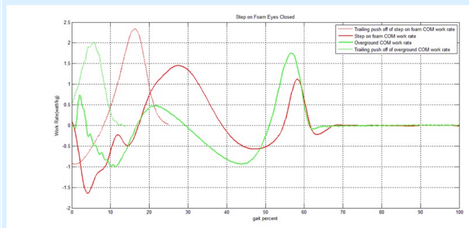
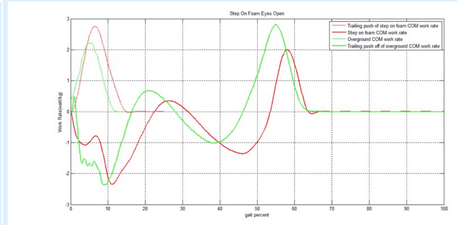
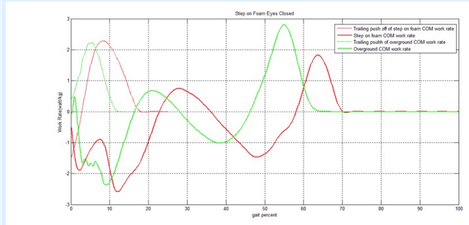
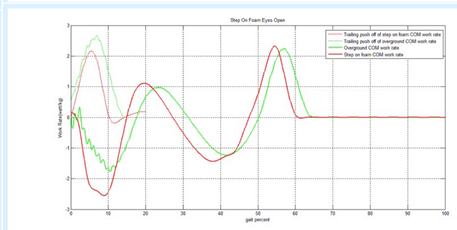
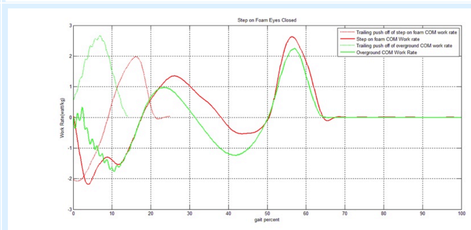


Step off foam

- Typical COM work rates of the step on foam and step off foam were investigated for both eyes open and eyes closed experiments.
- In eyes closed experiments, a late trailing push off with a bigger collision is expected for step on foam COM work rate. Since the trailing push off is late, collision should exceed the trailing push off. In the step off foam COM work rate, because it is a step down disturbance, a bigger collision would be observed.
- In eyes open experiments, because the test subjects saw the foam coming under their feet, they would have adjusted their step to step transitions. In step on foam com work rate, a bigger trailing push off would be expected since it is a step up height change. In step off foam COM work rate, a smaller trailing push off might be observed.

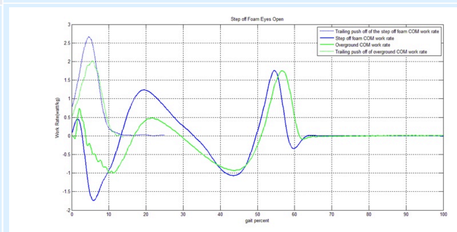
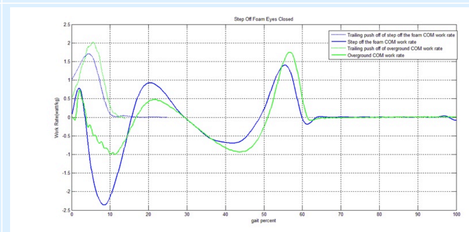
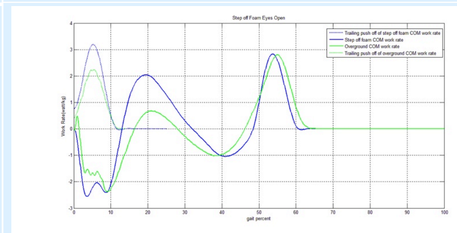
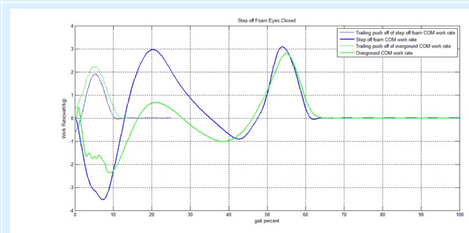
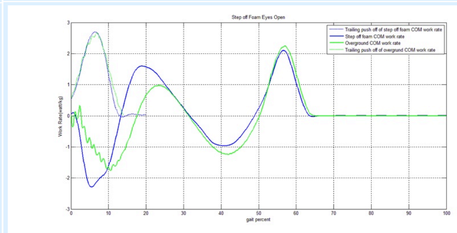
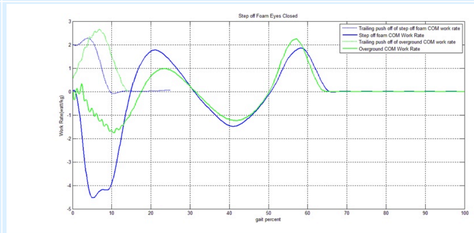
Results

STEP ON FOAM

	EYES OPEN	EYES CLOSED
TEST SUBJECT 1		
TEST SUBJECT 2		
TEST SUBJECT 3		

- In eyes closed tests, for all 3 test subjects it is obvious that trailing push off is late.
- When eyes are open, push off timing is probably adjusted, so that trailing push off is not late.
- Timings of all step to step transitions are different than over ground walking for both cases.
- Collisions of eyes closed tests are bigger than the collision of over ground walking.
- The trailing push off the 3rd subject is smaller than the trailing push off of over ground walking in eyes open tests. We suspect this happened due to the fact that our disturbance is not periodic, so test subjects may react differently and they may continue to compensate in the next COM work rate.

STEP OFF FOAM

	EYES OPEN	EYES CLOSED
TEST SUBJECT 1		
TEST SUBJECT 2		
TEST SUBJECT 3		

- In eyes closed tests, for all 3 test subjects it is obvious that collision is bigger than the collision of over ground walking and also the collisions of eyes closed tests.
- Rebounds of both eyes open and eyes closed cases are bigger than the rebounds of over ground walking. This might be a compensation due to the bigger energy loss in collision.
- It is interesting to observe in eyes open tests that the first and the second test subjects applied a bigger trailing push off although they saw that it was a step down height change.
- As observed in step on foam COM work rates, the timings of step to step transitions are also different in step off foam COM work rates.

Conclusions

- All four main parts of step to step transitions are changed in case of a step height disturbance. The change of trailing push off and collision influenced the whole COM work rate.
- The changes and timings of step to step transitions are severely influenced by visual feedback.
- Since our disturbance is not periodic, the amount of change in step to step transitions may differ due to how test subjects encounter the disturbance.

References

[1] Energetic Consequences of Walking Like an Inverted Pendulum: Step-to-Step Transitions Arthur D. Kuo, J. Maxwell Donelan, and Andy Ruina, *Exerc. Sport Sci. Rev.*, Vol. 33, No. 2, pp. 88–97, 2005.