Walking Coordination Changes With Incline

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INTRODUCTION

- As humans walk, gait mechanics change with respect to incline. For example, hip and knee angles become more flexed at touch down with increasing surface angles [1].
- Efficiency also plateaus at incline angles greater than 15%, equaling that of concentric muscle activity, suggesting that at these inclines work is only done to lift the body [2].
- Additionally, muscle activations have been shown to resemble different coordination patterns at extreme incline angles [3].
- Coordination variables, such as continuous relative phase (CRP) [4], might also reflect this change.
- Therefore, the purpose of this research was to utilize kinematic coordination variables to assess a potential walking coordination transition with incline and to evaluate the effect of speed on these variables.

METHODS

- 12 individuals (6M, 6F: height: 1.7±0.05m, weight: 65.13±5.3kg, age: 20.42±1.1 years) walked on a treadmill at 2 and 3 mph at inclines from 0% to 30% at 5% intervals.
- Reflective markers were placed on the pelvis and right leg and foot, from which segment and joint angles and angular velocities were determined. Kinematic data (120Hz) was collected for 20 seconds and filtered with a Butterworth Filter.
- This data was used to calculate CRP based on the methods explained in reference [4]. Three sagittal plane joint couples were calculated: Hip-Knee, Hip-Ankle, and Knee-Ankle. CRP is used to describe a couple as more in-phase (0°) or more out-of-phase (antiphase) (±180°).
- CRP was compared at each data point across the 7 inclines for the 3mph stages using an ANOVA (α=0.05). Cross-correlations were used to determine if the 2mph CRP was different from that of 3mph.

RESULTS

- At touch down, the hip and knee became more flexed, the thigh more horizontal and the shank more vertical. The thigh (R^2=.994) angles change curvilinearly with incline, such that, from 15%-30%, the thigh angle only changes 9° over the last four stages.
- There were significant differences ($p<0.05$) in all three joint couples during the stride cycle (black bars, Figure 1).
- All three couples were more in-phase at inclines of 15% and higher during the first 20% of the stride compared to lower inclines (Figure 1).
- Correlations between 2 and 3mph for all inclines were greater than 0.89. The largest differences with speed occurred on 0% incline in Hip-Ankle, lag of 3 (r=0.929) and in Knee-Ankle, lag of 4 (r=0.894) (Figure 2).

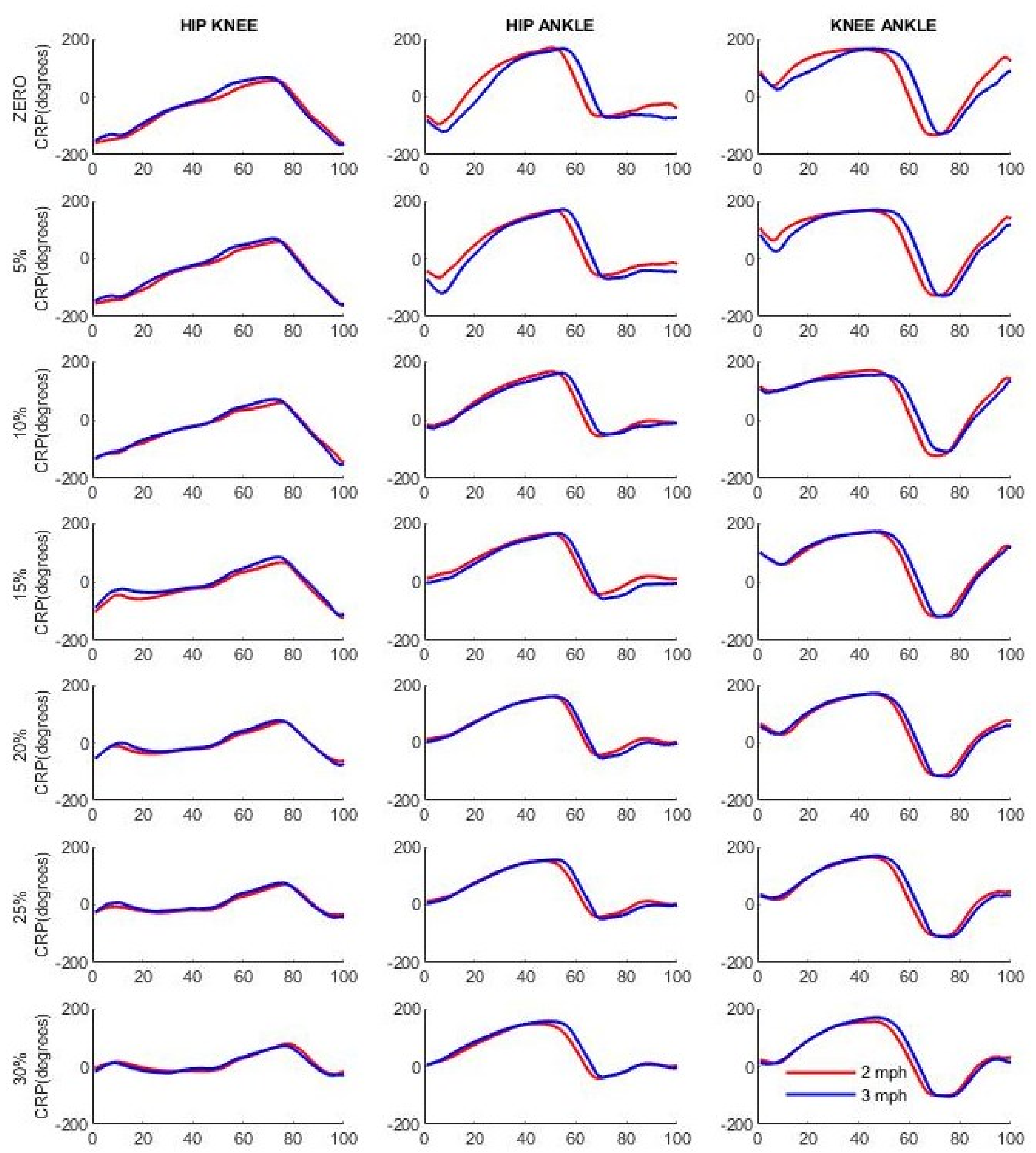

Figure 2: Joint CRP comparisons between 2 and 3 mph at all inclines.

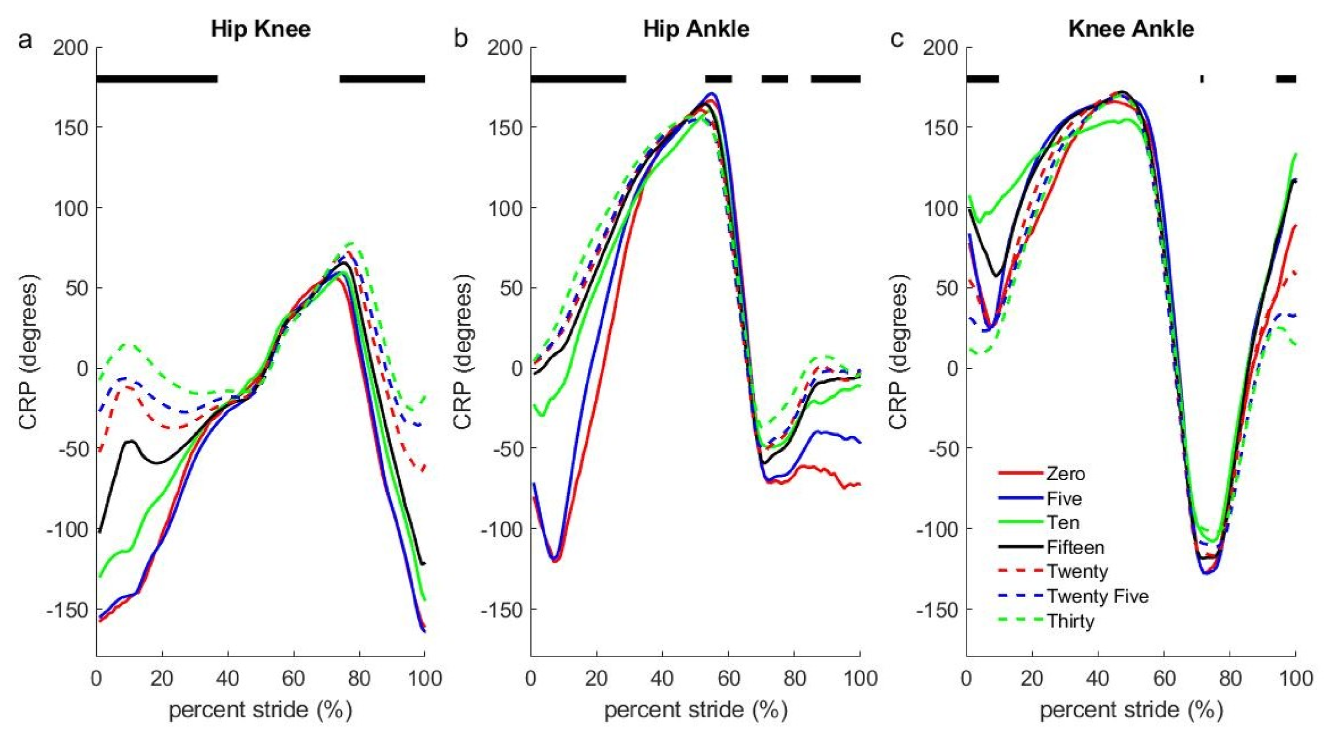

Figure 1: Average CRP for the three joint couples for all inclines through a complete stride.

DISCUSSION

- CRP values for all three sagittal plane joint couples were more in-phase during the first 20% of the stride for inclines at and above 15%.
- These changes in coordination did not appear to be affected by speed as all correlations between speeds were high, and lags were small, especially at inclines at and above 15%.
- These findings support the previous muscular activation studies [3] and indicate a synchronized effort at the joint level to lift the center of mass at these extreme inclines [2].
- This finding is interesting as it is the result of the interaction of the walking motor pattern and the environment (change in surface incline), although it is still unclear what constrains this coordination shift.

REFERENCES

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