Repetitive intermittent hypoxia improves motor learning and motor savings of adaptive mediolateral control during split-belt walking

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Summary

Active control of frontal plane mechanics is critical for maintaining balance in destabilizing environments. Individuals with neurological impairments experience a higher risk of falling and often adopt wider strides compared to able-bodied individuals [1]. However, adaptations in sagittal plane mechanics alone do not fully explain the variance in net metabolic power. Considering the association between frontal plane stability and metabolic cost [2], examining frontal plane mechanics during split-belt walking could provide further insight into adaptive strategies that influence dynamic balance control. We demonstrate that the initial learning and savings of unique interlimb frontal plane coordination strategies contribute to stability and are associated with a reduction in metabolic cost.

Introduction

We recently showed that repetitive exposure to intermittent hypoxia (IH) enhances both motor learning and motor savings of spatiotemporal features of walking coordination and kinetic asymmetry during split-belt walking. These sagittal plane adaptations were paralleled by further reductions in net metabolic power, indicating IH-induced gains in metabolic efficiency [3]. We examined whether repetitive IH exposure similarly enhances motor learning and savings of frontal plane adaptations while eliciting greater reductions in net metabolic power. We hypothesized that participants would initially increase step width and medio-lateral ground reaction force (ML GRF), but the magnitudes would decrease upon re-exposure to the perturbation. We further hypothesized that IH enhances the learning of frontal plane adaptations with greater reductions in net metabolic power compared to the controls.

Methods

Participants were randomly assigned to either the control group or the IH group. The IH intervention entailed five consecutive days of breathing 90 s bouts of hypoxic air (9% O_2) followed by 60 s bouts of normoxic air (21% O_2) for 15 cycles. On day 5, all participants performed four walking trials: baseline tied-belt, an initial adaptation with a 2:1 belt seed ratio, washout tied-belt, and a subsequent 2:1 speed perturbation. We quantified changes in step width, ML GRF, and net metabolic power during the perturbation trials. The 'fast leg' and 'slow leg' were analyzed independently based on respective treadmill speeds. Motor learning adaptations were assessed by analyzing changes during the initial adaptation (adapt 1), while motor savings evaluated retention from the initial to subsequent perturbation trials (adapt 2).

Results and Discussion

Bilateral increases in step width were observed during adapt 1, while only the slow leg reduced step width during adapt 2. Reductions in peak ML GRF during adapt 1 were leg specific, with the slow leg showing decreases during the braking phase (Fig 1A) and the fast leg during the propulsive phase (Fig 1B). The IH group uniquely exhibited bilateral reductions in step width from adapt 1 to adapt 2 as well as reduced slow leg peak ML GRF during propulsion (Fig 1C), indicating enhanced motor savings. We find significant correlation between ML kinetic adaptations in the fast leg and reductions in metabolic power for the control group (Fig 1D).

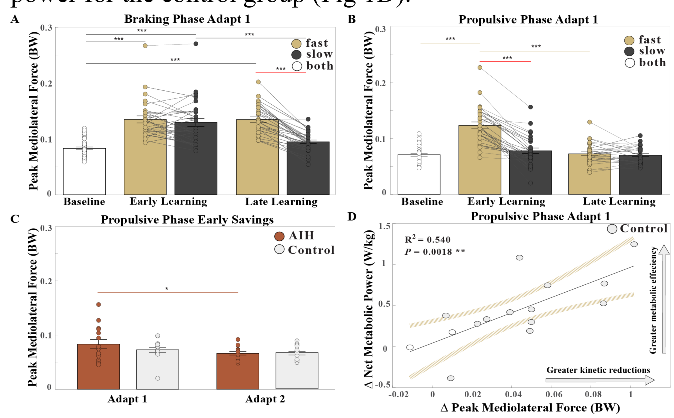

Figure 1: Adapt 1 peak ML GRF during the **A** braking phase and **B** propulsive phase. **C.** Propulsive phase of early savings for the slow leg. **D.** Association between net metabolic power and peak ML GRF during adapt 1 for the fast leg in control group.

Conclusions

Our results show that maintaining frontal plane force asymmetry contributed to metabolic efficiency during split-belt walking and that IH exposure enhanced the retention of prior strategies. Differences in leg dependent adaptations between the initial learning to motor savings phase suggest shifts from generalized anticipatory control to reactive adjustments. Notably, the savings of frontal plane adaptations are enhanced by IH. These insights could inform the design of clinical training approaches to improve dynamic balance and prevent falls in clinical populations.

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References

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