# MODULATION OF FORWARD PROPULSION, SUPPORT AND CENTER OF PRESSURE VIA GASTROCNEMIUS STIMULATION DURING GAIT

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## INTRODUCTION

The plantar flexors play an important role in modulating ground reactions during stance. For example, gait models predict that the gastrocnemius decelerates the center of mass (CoM) through mid-stance [1]. Thereafter, the gastrocnemius is believed to supplement the role of the soleus in generating forward propulsion and vertical support [1,2]. However, such model predictions have not been empirically substantiated. Further, the influence of gastrocnemius activity on the center of pressure (CoP) has not been studied but is important to consider given the link between abnormal gastrocnemius activity and equinus gait patterns [3]. In this study, we electrically stimulated the gastrocnemius at select times during stance, and measured the resulting changes in ground reactions and CoP. We tested the hypothesis that gastrocnemius activation during early stance would decelerate the CoM and induce a forward shift in the CoP, while activation later in stance would simultaneously induce forward propulsion and vertical support.

## CLINICAL SIGNIFICANCE

The gastrocnemius and soleus are often treated in individuals who exhibit equinus gait patterns. However, outcomes remain inconsistent. For example, some patients revert to equinus or exhibit crouch gait patterns after undergoing triceps surae lengthening procedures [4]. An understanding of gastrocnemius contributions to CoM and CoP motion is essential when investigating equinus gait and the cause of adverse outcomes.

## METHODS

Twenty healthy subjects participated in this study (24.5 ± 3.0 y, 66.4 ± 10.5 kg, 1.71 ± 0.10 m). Stimulating surface electrodes were placed over the mid muscle belly of the medial gastrocnemius. Subjects walked at their preferred speed (1.14 ± 0.10 m/s) on an instrumented split-belt treadmill (Bertec, Columbus, OH) that provided three-dimensional ground reactions under each foot. The vertical ground reaction was used to monitor heel strike events in real time. This information was used to trigger electrical stimulation of the gastrocnemius starting at 20, 30 or 40% of the gait cycle (GC) of a random stride (on average every $10^{th}$ stride). The stimulation pulse train consisted of 4 pulses delivered over a 90 ms window. In post-hoc analysis, we computed the average anterior and vertical ground reactions and CoP position over 50-ms windows following the onset of stimulation. The induced ground reaction measures were defined as the difference in force magnitudes and CoP between the stimulated stride and comparable measures in the preceding non-stimulated stride. Induced ground reaction measures were statistically compared using t-tests.

## RESULTS

Gastrocnemius stimulation at 20% of the GC induced a significant forward shift of the CoP and greater vertical force within 50 ms of stimulation onset. A decrease in the anterior ground reaction force was also seen, but occurred much later. Gastrocnemius stimulation at 30% GC induced a significant increase in the anterior and vertical ground reaction forces at 100 and 150 ms, respectively, but had no affect on the CoP. Stimulation at 40% GC induced a significant increase in the anterior ground reaction force during pre-swing.

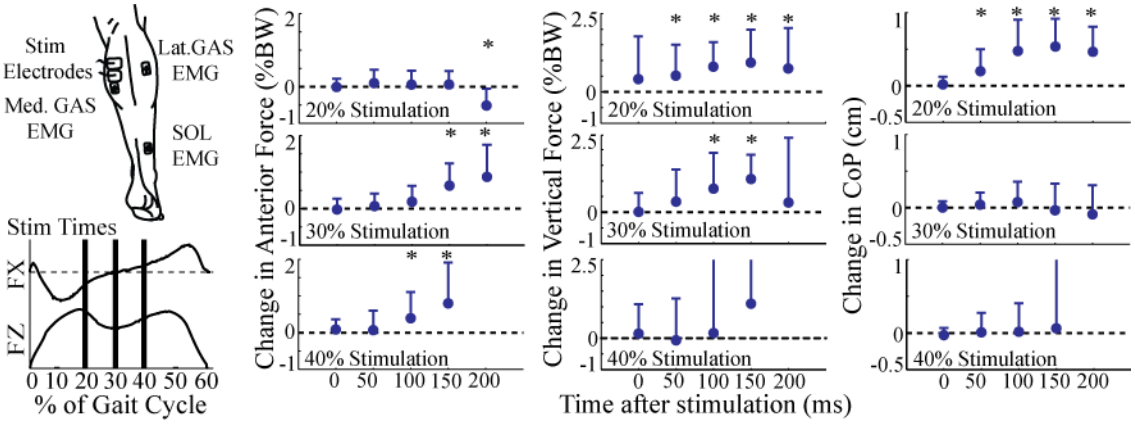


Figure 1. Medial gastrocnemius was stimulated via surface electrodes at 20, 30 or 40% of the GC. The resulting significant (*, $p<0.05$) changes in the ground reactions are denoted.

## SUMMARY/CONCLUSIONS

To our knowledge, this study represents the first attempt to directly measure ground reaction changes in response to selective muscle stimulation during gait. Notably, we found that stimulating the gastrocnemius early in stance induced an increase in vertical support and a rapid forward shift of the CoP. This action would drive the CoP toward the toes, and hence demonstrates the capacity of early onset gastrocnemius activity to contribute to equinus gait patterns [3]. Activation of the gastrocnemius at 30% of the gait cycle did not affect the CoP, but did induce simultaneous forward propulsion and vertical support of the CoM. This result is consistent with gait model predictions of normal gastrocnemius function [1,2]. Gastrocnemius stimulation during late stance causes an increase in forward propulsion during pre-swing. Vertical support also tended to be higher in pre-swing, but variability was high in this phase. Our future studies will investigate soleus function in order to empirically discriminate the role of individual plantar flexors during gait.

## REFERENCES

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## ACKNOWLEDGMENTS

NIH AR057136, NIH T90 DK070079, Dr. James McCarthy, Nick Harrison, Rachel Lenhart