SPM analysis of ankle kinetics during single-leg hopping in children and adults
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I. BACKGROUND
Hopping is a fundamental motor skill that follows the constraints of a spring-mass model [1] and demands effective stretch-shortening cycle function [2]. Pre-adolescent children are still developing stretch-shortening cycle parameters such as tendon stiffness and show different whole body vertical stiffness and frequency control compared to young adults [3]. However, there is a paucity of evidence regarding the loading of the lower limb joints during hopping. In this study, we assessed children and young adults’ ankle, knee, and hip joint sagittal plane angles, moments, and power across varying frequencies during stance phase using statistical parametric mapping (spm1d).

II. METHODS
Eleven children (5F/6M, 9.35 (1.44) years) and eleven young adults (4F/7M, 23.79 (2.83) years) participated. Subjects hopped at four frequency conditions relative to their self-selected preferred frequency: slow (80%), preferred (100%), moderate (120%), and fast (140%). Subjects hopped for 20 second bouts and were guided by a metronome. A motion capture system (Vicon, Oxford, UK) collected kinematic data and a floor embedded force plate (AMTI, MA, USA) captured kinetic data. Time normalized joint angles, moments, and power were determined using custom MATLAB scripts (MathWorks, Natick, MA, USA). SPM1D analysis was conducted using the Statistical Parametric Mapping package for python.

III. RESULTS & DISCUSSION
Young adults demonstrated more proficiency at modulating the ankle joint compared to children, particularly at the slow condition (Fig. 1). When hopping slow, young adults increased dorsiflexion, reduced the extensor moment, and reduced both negative and positive power, while children did not. When hopping faster than preferred, children reduced dorsiflexion during stance but did not concurrently increase the extensor moment. In addition, children were not able to increase moments at the ankle joint when hopping faster and would rely on more proximal joints. In comparison, at the knee and hip joints, children illustrated more adult-like strategies.

IV. CONCLUSION
This study highlights developmental differences during single-leg hopping in-place such that the ankle joint attenuates forces when moving slower than preferred and amplifies moment when moving faster than preferred. Minimal differences of the knee and hip joint suggests proximal to distal maturation of the lower limb joints. These findings can be used to inform the design and implementation of rehabilitation and medical devices fit to the movement patterns of children.

V. ACKNOWLEDGMENT
Special thanks to the participants and their families.

REFERENCES

Fig. 1. Ankle joint angle and moment time normalized to stance with corresponding spm1d results. Main A indicates group main effect, Main B indicates condition main effect, and Interaction AB indicates group by condition interaction.