The effect of exercise on fetlock joint moments during walking in growing foals

Melany D. Opolz[1], Sara G. Moshage[2], Samantha M. Hammack[3], Griffin C. Sipes[2], Marcus G. Pandy[4], Annette M. McCoy[3,5], Mariana E. Kersh[2,5,6]

[1]Chemical and Biomolecular Engineering, University of Illinois Urbana-Champaign, Urbana, IL, USA
[2]Mechanical Science and Engineering, The Grainger College of Engineering, University of Illinois Urbana-Champaign, IL, USA
[3]Veterinary Clinical Medicine, University of Illinois Urbana-Champaign, Urbana, IL, USA
[4]Mechanical Engineering, University of Melbourne, Parkville, VIC, Australia
[5]Beckman Institute for Advanced Science and Technology, University of Illinois Urbana-Champaign, Urbana, IL, USA
[6]Carle Illinois College of Medicine, University of Illinois Urbana-Champaign, Urbana, IL, USA
*Email: mopolz2@illinois.edu

Summary

Exercise strengthens bones, but the effect of exercise on bone loading during habitual activity, such as walking, is unclear. We used joint moments as a first-order approximation of bone loading to assess the impact of an exercise intervention during early growth using an equine model. There were no significant changes in torques but a potential sex-specific response.

Introduction

Exercise is a mechanism for improving bone strength [1] wherein increased strains, due to muscle forces, above those experienced during normal movement promote bone formation [2]. Joint moments, which are the net result of muscle forces, serve as a "first order approximation" of bone loading [3]. However, the effect of exercise when young on joint moments during baseline activities remains unclear. Therefore, the aim of this study was to assess the effect of exercise on distal forelimb joint moments during walking in growing foals.

Methods

Six foals underwent an 8-week exercise intervention starting at 8 weeks of age (5 days: 1200m/day at ~4 m/s; 35 days: 1600m/day at ~5 m/s). Six foals served as non-exercised controls. Video-based motion capture data of foals walking was collected in the field at the start and end of the exercise intervention. Video data were processed (MATLAB R2021.a) and the left forelimb segment markers were tracked using machine learning (DeepLabCut v2.3).

Velocity (v) was calculated from shoulder marker displacements over 3 consecutive strides. Limb length (l) was the vertical distance between elbow and hoof markers during quiet stance. Ground reaction forces were estimated using the Froude number ($Fr = v^2/(g * l)$) [4]. A musculoskeletal model of the forelimb [5] was scaled to each subject (OpenSim v3.3) and joint torques were calculated using inverse dynamics. For each foal, 3 stance phases were averaged and normalized to body mass. Non-normal continuous data (Shapiro-Wilk) were analyzed using Statistical non-Parametric Mapping (SnPM, spm1d vM.0.4.10) [6], with post-hoc paired t-tests and Benjamini-Hochberg correction. Multiple linear regression models, with and without sex as a variable, were used to evaluate the strongest predictors of maximum torque. Percent changes were calculated from the median of maximum torque in each group (R v4.2.2).

Results and Discussion

Viable trials for analysis included data from 5 exercised foals (3 females) and 4 female controls. There was a modest decrease in torques due to growth (control) and growth plus exercise (Figure 1A). The Froude number, growth, and exercise status explained 22% of the fetlock maximum torque (p=0.13). When including sex, the percentage of explainable max torque increased to 36% (p=0.08). The strongest predictors were Fr (β=1.86, p=0.02), and the interaction between growth and sex (β=0.25, p=0.08). Exercised females had a 26.5% decrease in maximum torques during walking compared to non-exercised females (-10.3%). There was very little change in the fetlock torques of exercised males (-2.9%) (Figure 1B).

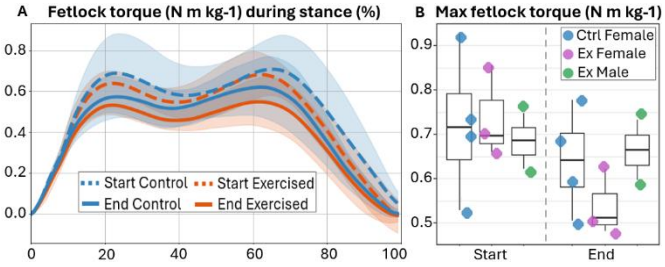

Figure 1: **A**. Continuous torque data during stance phase at start and end of intervention by group (mean: lines; s.d.: shaded areas). **B**. Max torque at start and end of intervention by group and sex.

Conclusions

Growth alone had a modest effect on fetlock torques during walking. While this study is limited by sample size, these data suggests that exercise may have a sex-specific effect on habitual activity when young. More work is needed to better understand the effect of exercise on normal walking.

References

[1] Warden SJ et al. (2014). *PNAS*, **111**: 5337-5342. [2] Pivonka P. (2018) *Multiscale Mechanobiology of Bone Remodeling and Adaptation*; Springer Intl. [3] Wang MY et al. (2006). *Clin Biomech*, **21**: 717-725. [4] Opolz MD et al. (2024), In: *Proceedings of ASB*; Madison, WI. P1-137. [5] Harrison SM et al. (2010). *JEB*, **213**: 3998-4009. [6] Pataky TC. (2012). *CMBBE.*, **15**: 295-301