BOTULINUM TOXIN INJECTIONS DO NOT ALTER MUSCULOSKELETAL LOADING AND BONE GROWTH IN CHILDREN WITH CEREBRAL PALSY

Hans Kainz (1, 2), Bryce Killen (2), Anja Van Campenhout (3), Kaat Desloovere (3), Jose Manuel Garcia Aznar (4), Sandra Shefelbine (5), Ilse Jonkers (2)

1. University of Vienna, Austria; 2. KU Leuven, Belgium; 3. University Hospital Leuven, Belgium; 4. University of Zaragoza, Spain; 5. Northeastern University, Boston, USA

Introduction

Many children with cerebral palsy (CP) are born with typical bones but develop bone deformities during growth due to abnormal bony loadings caused by their pathological gait pattern [1, 2]. While Botulinum toxin A (BTX) injections are planned to reduce spasticity [3], their impact on musculoskeletal loadings and bone growth remains unclear. Hence, in this study we used a multiscale modeling approach to investigate the impact of BTX injection on musculoskeletal loading and femoral bone growth.

Methods

Motion capture data of five typically developing (TD, 8.1±1.9years, 29±5kg, 1.3±0.1m) and nine children with spastic diplegic CP (7.5±1.2years, 24±4kg, 1.2±0.1m), before and after multi-level BTX treatment, were used for dynamic simulations of gait. A pediatric musculoskeletal model was scaled to each participant. Muscle and joint contact forces (JCF) were calculated in OpenSim [4] and used as loading conditions in a finite element (FE) model of a femur, developed from magnetic resonance images of a TD child. Adaptive mechanobiological FE analyses were used to predict femoral growth trends [5]. Ashworth spasticity scores [6], joint kinematics, hip JCF and growth trends were compared before and after BTX injections.

Results

Ashworth spasticity scores showed a significant decrease in spasticity for hip flexors, hip adductors and gastrocnemius muscles after BTX treatments. Differences in joint kinematics between CP and TD participants only slightly decreased from an average gait profile score [7] of 9.3° to 9.1° after BTX treatments. Hip ab-/adduction (-0.7°), knee flexion/extension (-2.8°) and ankle dorsi-/plantarflexion (-1.0°) showed the biggest improvement in joint angles.

Maximum hip JCF were higher in TD than in children with CP (Figure 1A). On average, hip JCF were less posterior-oriented in children with CP compared to TD children (Figure 1B). BTX treatment had no impact on hip JCF. Growth simulation in TD led to an average decrease in femoral neck-shaft angle (NSA) of -0.5° and anteversion angle (AVA) of -0.7°. In our participants with CP, the AVA decreased less than in the TD participants (-0.5° for pre- and post-BTX). The change in NSA was similar between TD and children with CP (-0.5° for pre- and post-BTX). BTX treatment had no impact on femoral growth simulations.

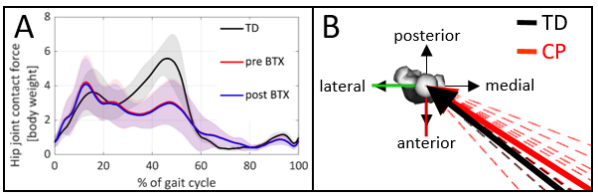

*Figure 1: **A)** Average hip JCF from our TD children and children with CP before and after BTX injections. The shaded area represents +/- one standard deviation of the resultant hip JCF. **B)** Orientation of the hip JCF in the transverse plane. Solid arrows represent the average direction of each group (TD and CP). Dashed arrows represent the individual CP and TD participants.*

Discussion

This is the first study that showed that BTX has no impact on hip JCF and femoral growth although spasticity was reduced and joint kinematics slightly improved after BTX treatments.

In our participants with CP, spasticity scores decreased after BTX treatment, which is in agreement with previous work [3]. Gait profile scores of our participants were typical for children with CP with a Gross Motor Function Classification Score of 2 [7].

Previous bone growth studies based on multi-scale simulations were limited to small sample sizes (N<4) [5, 8]. Hence, our study is the first investigation, which compared two different populations in a comprehensive way. AVA decreased less in CP compared to TD children, which is in agreement with the increased AVA commonly observed in children with CP [1]. The less posterior-oriented hip JCF in children with CP likely caused this effect. Furthermore, hip JCF orientation and consequently femoral growth simulations showed a wide dispersion in children with CP, whereas our TD participants walked with a more consistent hip JCF orientation. Hence, the used modeling framework has the potential to differentiate between children who are likely to develop femoral deformities and who not. Furthermore, the workflow might help to select the most promising treatment option for each child in the future.

References

1. Bobroff et al, Clin. Orthop Relat Res, 364:194-204, 1999.
2. Lundy et al, J Pediatr Orthop, 18: 528-534, 1998.
3. Graham et al, Nat Rev Dis Prim, 2: 1-25, 2016.
4. Delp et al, IEEE Trans Biomed Eng, 54: 1940-1950, 2007.
5. Carriero et al, CM Biomech Biomed Eng, 14:253-62, 2011.
6. Bohannan et al, Phys Ther, 67:206-207, 1987.
7. Baker et al, Gait & Posture, 30:265-269, 2009.
8. Yadav et al, Biomech Mod Mech.biol, 16: 1869-83, 2017.