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ORIGINAL RESEARCH

Site-Specific Transmission of a Floor-Based, High-Frequency, Low-Magnitude Vibration Stimulus in Children With Spastic Cerebral Palsy

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Abstract

Objective: To determine the degree to which a high-frequency, low-magnitude vibration signal emitted by a floor-based platform transmits to the distal tibia and distal femur of children with spastic cerebral palsy (CP) during standing.

Design: Cross-sectional study.

Setting: University research laboratory.

Participants: Children with spastic CP who could stand independently (n=18) and typically developing children (n=10) (age range, 4−12y) participated in the study (N=28).

Interventions: Not applicable.

Main Outcome Measures: The vibration signal at the high-frequency, low-magnitude vibration platform (approximately 33Hz and 0.3*g*), distal tibia, and distal femur was measured using accelerometers. The degree of plantar flexor spasticity was assessed using the Modified Ashworth Scale.

Results: The high-frequency, low-magnitude vibration signal was greater ($P<.001$) at the distal tibia than at the platform in children with CP (.36±.06*g* vs .29±.05*g*) and controls (.40±.09*g* vs .24±.07*g*). Although the vibration signal was also higher at the distal femur (.35±.09*g*, $P<.001$) than at the platform in controls, it was lower in children with CP (.20±.07*g*, $P<.001$). The degree of spasticity was negatively related to the vibration signal transmitted to the distal tibia (Spearman $\rho=-.547$) and distal femur (Spearman $\rho=-.566$) in children with CP (both $P<.05$).

Conclusions: A high-frequency, low-magnitude vibration signal from a floor-based platform was amplified at the distal tibia, attenuated at the distal femur, and inversely related to the degree of muscle spasticity in children with spastic CP. Whether this transmission pattern affects the adaptation of the bones of children with CP to high-frequency, low-magnitude vibration requires further investigation.

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Children with physical disabilities, such as cerebral palsy (CP), have reduced muscle[1] and bone[2,3] mass and quality, especially in the lower extremities. This musculoskeletal deficiency in children with CP is associated with less force−generating capacity of the muscles[4] and a higher incidence of low-energy fractures in the lower extremities.[5] Because children with CP have difficulty participating in physical activities,[6] leading to reduced mechanical loading on their skeletal system, identifying alternate non-pharmacologic treatments is of interest.[7]

Studies have shown that a floor-based, high-frequency, low-magnitude vibration signal has an anabolic effect on bone in various populations,[8,9] including children with CP.[10,11] There are also studies showing no effect of high-frequency, low-magnitude vibration on bone[12,13] or an inconsistent effect across sites.[14,15] It is plausible that the effectiveness of high-frequency, low-magnitude vibration is dictated by the degree to which the vibration

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signal is transmitted to a particular bone site, similar to the site-specific effects of exercise.[16] The tibia and femur are of interest in children with CP because they are the most commonly fractured bones, and the distal femur is the most commonly fractured site.[5] Unfortunately, the transmission of high-frequency, low-magnitude vibration to key bone sites in children with CP has not been studied.

The primary aim of this study was to determine the degree to which a high-frequency, low-magnitude vibration signal emitted by a floor-based platform transmits to the distal tibia and distal femur of children with spastic CP during standing. An amplification of high-magnitude vibration at the ankle and an attenuation at the knee has been observed in typically developing children.[17] Whether a similar profile is exhibited in children with spastic CP using a lower magnitude vibration is unknown. Toe standing, which is common in children with spastic CP, has been shown to attenuate vibration at the ankle and knee.[18] Therefore, we hypothesized that the high-frequency, low-magnitude vibration transmission would be lower in children with spastic CP than typically developing children. We also hypothesized that there would be an inverse relation between the degree of spasticity and vibration transmission in children with CP.

Methods

Participants

Children with spastic CP (age range, 4−12y) at the levels of I to III using the Gross Motor Function Classification System (GMFCS) were recruited from the Nemours AI duPont Hospital for Children, Wilmington, Delaware. Children were excluded if they were unable to stand independently, if they had any metal rods in their thigh or leg, or if they had a surgery involving the musculoskeletal system or any antispastic medication (eg, botulinum toxin) within the last year. Eighteen children with CP were tested. Eight of the children had ≥1 previous surgery, including adductor lengthening (n=1), adductor tenotomy (n=1), adductor release (n=1), hamstring lengthening (n=6), tendoachilles lengthening (n=1), gastrocnemius recession/lengthening (n=4), and botulinum toxin (n=8). Thirteen of the children had equinus deformity and walked on their toes. Five of the children were taking antiepileptic medication. Typically developing children (n=10) in the same age range as the children with CP, between the 5th and 95th percentiles for height and body mass and without a history of chronic medication use, were recruited from the Newark, Delaware, community to serve as controls. This study was approved by the Nemours AI duPont Hospital for Children and the University of Delaware Institutional Review Boards. Participants and their parents gave written assent and consent, respectively, before testing.

Study design and procedures

A within-subject and between-group comparison design was used. Anthropometrics, pubertal development, degree of spasticity, gross motor function, and vibration transmission were assessed during a single visit at the University of Delaware.

List of abbreviations:

CP **cerebral palsy**
GMFCS **Gross Motor Function Classification System**
MAS **Modified Ashworth Scale**

Anthropometrics

Height and body mass were measured while the children were wearing minimal clothing and were without shoes or braces. Height was measured to the nearest 0.1cm using a stadiometer (Seca 217[a]). Body mass was measured to the nearest 0.1kg using a weighing scale (Detecto D1130[b]).

Tanner staging

Tanner staging was conducted by a physician assistant to assess sexual maturity of each participant. The Tanner stage rating scale ranges from I to V, with I indicating no sign of sexual maturity and V indicating full sexual maturity.[19,20]

Modified Ashworth Scale

Ankle plantar flexor tightness was assessed in children with CP while the participant was lying on a table in a supine position using the Modified Ashworth Scale (MAS). The grading system ranges from 0 to 4, with 0 indicating presence of normative tone and 4 indicating muscle rigidity in flexion/extension.[21] The grade for each limb was based on an average grade of 3 trials. The reliability of spasticity assessment of the plantar flexors using the MAS was determined by evaluating 12 children with CP (age range, 4−11y) on 2 different days, 1 month apart. Cohen $\kappa=.71$ ($P<.001$) indicates good reliability.

Gross Motor Function Classification System

Gross motor function was assessed using the GMFCS, which ranges from I to V. Only those children who were GMFCS level I (walks without restrictions), II (walks without assistive device; limitations walking outdoors and in the community), or III (walks with assistive mobility device; limitations walking outdoors and in the community)[22] participated in our study. The reliability of gross motor function assessment using the GMFCS was determined by evaluating 12 children with CP (age range, 4−11y) on 2 different days, 1 month apart. Cohen $\kappa=.74$ ($P<.001$) indicates good reliability.

Vibration transmission

Participants stood on a high-frequency, low-magnitude vibration platform (Juvent 1000 Motion Therapy System[c]) for 3 consecutive conditions (previbration, vibration, postvibration) of 30 seconds per condition. The platform delivered a sinusoidal vertical vibration signal of approximately 0.3*g* at a frequency of 30 to 37Hz. No vibration was transmitted during the pre- and postvibration conditions, which were immediately before and immediately after the vibration condition, respectively. The platform was divided into right and left halves, and the center of each foot was placed in the center of the respective half. The participants stood on the platform without shoes, socks, or braces. They were instructed to stand on the platform as still as possible in a relaxed positon and were encouraged to stand without support. Although all children were able to stand without assistance, poor balance is an issue associated with CP, which can be exacerbated by antiepileptic medications.[23]