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Case Report

Health benefits of seated speed, resistance, and power training for an individual with spastic quadriplegic cerebral palsy: A case report

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Abstract. Children with moderate to severe cerebral palsy are at risk for low bone mass for chronological age, which compounds risk in adulthood for progressive deformity and chronic pain. Physical activity and exercise can be a key component to optimizing bone health. In this case report we present a young adult male with non-ambulatory, spastic quadriplegia CP whom began a seated speed, resistance, and power training exercise program at age 14.5 years. Exercise program continued into adulthood as part of an active lifestyle. The individual had a history of failure to thrive, bowel and bladder incontinence, reduced bone mineral density (BMD) for age, and spinal deformity at the time exercise was initiated. Participation in the exercise program began once a week for 1.5–2 hours/session, and progressed to 3–5 times per week after two years. This exercise program is now a component of his habitual lifestyle. Over the 6 years he was followed, lumbar spine and total hip BMD Z-scores did not worsen, which may be viewed as a positive outcome given his level of gross motor impairment. Additionally, the individual reported less back pain, improved bowel and bladder control, increased energy level, and never sustained an exercise related injury. Findings from this case report suggest a regular program of seated speed, resistance, power training may promote overall well-being, are safe, and should be considered as a mechanism for optimizing bone health.

Keywords: Cerebral palsy, quadriplegic, bone mineral density, exercise

1. Introduction

Children with moderate to severe cerebral palsy (CP) are at risk for low bone mineral density for chronological age [1], which increases risk for fractures, deformity, and chronic pain in adolescence and adulthood [2–5] Of particular concern is the neurogenic pain experienced from progressive spinal deformity [6] Physical activity in childhood may be a key component to optimizing skeletal health across the lifespan [7] Exercise that produces high ground reaction forces creates increased bone mass in the hips and spine of pre-pubescent children with typical develop-

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ment [8–10]. Children and adolescents with moderate to severe CP have less opportunities for physical activity and exercise [11], and are less likely to engage in exercise programs that include speed and power training and produce greater than body weight forces. A novel idea is to use seated speed, resistance, and power training exercises as a component of promoting well-being and skeletal health of individuals with moderate to severe CP.

Bone strength can mitigate risk for fractures and progressive deformity [12]; and bone shape, mass, and micro-architecture determine bone strength [13]. Changes in bone micro-architecture produced by exercise can result in large changes in bone strength, with only small changes in bone mass [14]. Areal bone mineral density (BMD) calculated from dual-energy x-ray absorptiometry (DXA) measures bone mass in children [15], and it is often used to infer bone strength. However, BMD may underestimate changes in bone strength, as it is a two dimensional measure. Measures such as peripheral quantitative computed tomography (PQCT) may provide better visualization of bone architecture related to bone strength. Nonetheless, there is a paucity of information on longitudinal bone health in individuals with moderate to severe CP in response to exercise.

The purpose of this case report is to describe the health benefits of a seated speed, resistance, and power training exercise program on long term health outcomes in a young male with spastic quadriplegic CP. Bone outcomes are reported as exercise is a mechanism that can influence bone health. The experience of the individual in the case report supports the safety of speed, resistance, and power training for children and adolescents with moderate to severe CP.

1.1. *Case description: Birth to 13 years of age*

Institutional review board approval was obtained to perform a retrospective chart review, and interviews with the individual and care providers. Additionally, the Health Information and Portability and Accountability Act procedures were followed for describing this case report. The individual in this case report was born at 28 weeks gestation, sustained anoxia at birth, and presented with periventricular leukomalacia. Functional classification levels include: Gross Motor Functional Classification System [GMFCS] level IV, with some characteristics of GMFCS V; Manual Ability Classification Scale level III; and Communication Function Classification Scale level I [16–18]. Risk factors for low BMD for age included: high GMFCS level, difficulty with feeding, and below normal body mass for age [1].

After a 4-month stay in the neonatal intensive care unit, the individual was discharged to home and followed at a complex care clinic at a large Children's Hospital. He received care from gastrointestinal-nutrition clinic for dysphagia, gastro-esophageal reflux (GERD) managed with Cisapride, and constipation. At 3 years of age, he received a wheelchair due to the inability to sit and walk independently, and had a gastrostomy tube (G-tube) placement due to his poor oral intake and failure to thrive. Orthopedics followed him for management of musculoskeletal deformities. At 4 years of age, he had bilateral femoral de-rotational osteotomies to address femoral anteversion and coxa valgus.

At 7 years of age, physical therapy consisted of standing with braces, and assisted steps in parallel bars. He complained of low back pain and presented with knee flexion contractures. At 8 years of age, he continued to be medically fragile, with low weight and poor intake, and had a prolonged and complicated recovery after hardware removal at the hip and hamstring lengthenings. The individual became increasingly anxious and depressed.

At 12 years of age, the individual continued with complaints of GERD, G-tube feedings, constipation (managed with Miralax), urinary incontinence (managed with Detrol), and low bone mineral density for chronological age (lumbar spine BMD Z-score of -2.7), with adequate levels of testosterone and parathyroid hormone (Table 1). During this time, his calcium and vitamin D were monitored, medications for anxiety and depression were started, and he spent $\sim$ 60 minutes/day in a daily weight bearing in a stander.

At 13 years of age, he was diagnosed with a 50° scoliosis in the lumbar spine and had continued complaints of low back pain. He managed his bowel and bladder control with Miralax and Detrol, and continued his medications for anxiety and depression. Despite reduced bone mass of the lumbar spine, his calcium and vitamin D serum values were within normal ranges, but supplementation was continued to optimize levels. At this time, contractures were present in both upper and lower extremities, with the lower extremities more involved than the upper extremities, and the left side more than the right.

1.2. *Exercise program: 14 to 20 years of age*

The individual and his family were frustrated with traditional rehabilitation approaches that focused on

Table 1
Clinical and laboratory values over time

Age of Patient	12 years	13 years	14 years¶	15 years	17 years	20 years
Weight (kg)		33.6		34.4	34.8	35.7
Calcium (mg/dL)		10.5	9.7	10.9	9.4	
Phosphorus (mg/dL)		3.9		4.2	4.0	
Magnesium (mg/dL)		2.3		2.5	2.4	
Alkaline Phosphatase (unit/)L		211		142	88	
Parathyroid hormone (PTH)		18.4 (pg/mL)	24.6 (pg/mL)		24 (pg/mL)	
1,25-Dihydroxy Vitamin D (pg/mL)		61				
25-Hydroxy Vitamin D (ng/mL)		46	60	36	57	
LH (Lutenizing Hormone) (IU/L)		11.97	8.26		7	
Testosterone (serum) (ng/dL)	203	428				203
Testosterone (free) (pg/mL)	26	47				26
Testosterone (ng/dL)			176		482	
Lumbar Spine BMD Z-score	−2.7^ [−2.0 ± 0.2]	−2.5^		−2.4^	−2.3* [−2.0 ± 0.2]	−2.6*
Lumbar Spine (aBMD; g/cm^2)	0.445	0.529		0.616	0.722	0.805
Total Right Hip BMD Z-score		−3^				−2.2*
Total Right Hip (aBMD; g/cm^2)		0.541				0.703
Left Distal Femur (aBMD; g/cm^2)						
R1		0.400				0.512
R2		0.514				0.696
R3		0.741				0.801
Left Distal Femur BMD Z-score						
R1		−3.6				Z-scores not
R2		−3.7				reportable
R3		−3.1				for adults

^Performed on a Hologic 4500 scanner with Delphi upgrade; *Performed on a Hologic Discovery A scanner change in the analytic software used for adults, and cannot be compared to prior Z-scores; ¶Exercise program initiated after this examination; (Mean BMD values reported for age range 12.0–19.0 years in [1]).

positioning and passive movements. The individual was interested in mixed martial arts and boxing, and convinced his family to allow him to begin training to become a competitive wheelchair boxer. Training at a gym with a strength and conditioning coach began one time per week at 14.5 years of age. The basic components of each work out are outlined in Table 2 and included the following: 1) *Warm-up*: flexibility exercises focused on the spine, hips, shoulders, and elbows. 2) *Speed training*: punching with focus mitts using both heavy and speed bags. 3) *Strength and power training*: focused on form in the available active range, beginning at 50% of 1 repetition max (RM), with repetitions and intensity increased as tolerated. Lower extremity and trunk training used body mass as resistance at the start of the program. Standard commercial resistance training equipment was used, and a trainer was available at all times to spot the individual through each exercise. 4) *Cool down:* exercises included active range of motion of shoulder and elbows, with gentle holds at end of range. All exercises were performed with the usual safety gear of the sport, and a trainer assisted with warm up exercises, and set up and spotting for other exercises.

1.3. *Response to exercise program: 14 to 20 years of age*

The individual had a positive response to the exercise-training program. When the exercise program was initiated, the individual was unable to lean forward in his chair, weight shift or rotate trunk in chair for repositioning or reaching, left passive elbow extension was limited to half the range, and he had limited solid food intake. Exercise began once a week at a gym with a trainer. After a year, frequency increased to two times a week for 1.5 hours each session. Back pain was resolving with exercise; medication for mood continued.

By 15 years of age, his scoliosis progressed to 67°; and a spinal fusion was recommended by his orthopedic team to address restrictive lung disease and progressive spinal deformity. He refused surgery. He con-

Table 2
Current Training Protocol*

Warm up	Hip Abduction Stretches Hip and Knee Extension Supine Trunk Stretches (rotation and traction)	Frequency: 3–5 x week Volume: 3–5 reps, 1–2 sets Intensity: 20–30 sec holds to end range Velocity: n/a; static holds
Upper Extremity Speed Training	Focus Mitts Heavy Bag Small Bag Arm Ergometer	Frequency: 4–5 x week Volume: ⩾ 6 intervals (rounds) Intensity: 5 minutes each exercise with 30 sec rest between; occasionally last interval to burnout Velocity: as fast as possible
Upper Extremity Resistance Training	Biceps curls dumbbells Biceps curls with bars Wrist curls Shoulder lifts: front and side Shoulder press Shoulder holds	Frequency: 3–5 x week Volume: 3 sets of 20 reps Intensity: 50%–75% of 1 Repetition Max (RM) Velocity: Moderate
Upper Extremity Power Training	Lat pull downs Pull Ups Weight jabs Triceps overhead lifts	Frequency: 3–5 x week Volume: 4 sets 20 reps Intensity: partial body weight by using spotter assistance; or 50–60% of 1 RM Velocity: as fast as possible with concentric, slow eccentric
Trunk Endurance training	Medicine Ball Pass	Frequency: 4–5 x week Volume: 2 sets of 20 reps Intensity: 50% of 1 RM Velocity: Moderate
Lower Extremity Resistance Training	Long Arc Quadriceps Extension Sit to Stand	Frequency: 3–5 x week Volume: 3 sets of 10 reps Intensity: 75% of 1 RM; or use of body weight Velocity: Moderate
Cool Down	Shadow Boxing Shoulder Horizontal Adduction and Abduction Trunk Rotations with Flexion Elbow and wrist extension	Frequency: 4–5 x week Volume: 1 interval Intensity: 3–5 minutes; active movement, no resistance Velocity: gentle, slow, to end range with active movement and hold.

*Exercises under dosed according to [23]. For more details on optimal dosing parameters see [22].

tinued to exercise, and increased frequency to 2–3 times per week, 1.5–2 hours per session. Endocrinology team reports revealed lumbar spine BMD Z-score of −2.5 and right hip BMD Z-score of −3, with calcium and vitamin D ranges within normal ranges. His low BMD was not due to a vitamin D deficiency; however, given issues with his GI function, he continued his calcium and vitamin D supplements to optimize his bone health. His energy and appetite continued to improve, as did his attendance and performance at school. His appetite increased as did his intake, and the G-tube was removed. The individual constructed a swivel seat to improve his ability to rotate the trunk during punching related activities.

He continued with the exercise program 2–3 times per week, 1.5–2 hours per session at 16 years of age. His scoliosis progressed to more than 70°. Endocrinology team reported lumbar spine BMD Z-score of −2.4, with no hip scan done at this age.

The individual continued to exercise, increasing his training to 3–5 times per week for 1.5–2 hrs per session by 17 years of age. By this time, he increased the amount of weight lifted which resulted in improved upper extremity muscle mass and active range of motion of the trunk, upper, and lower extremities. The gains in strength translated to the ability to assist with transfers, improved sitting balance and function, improved GERD, improved oral intake, improved bowel control, and reduced back pain. He continued with medication for anxiety and depression, and continued calcium and vitamin D supplementation. Endocrinology team reports revealed lumbar spine BMD Z-score of −2.3, with normal serum values of testosterone, calcium and vitamin D.

At 20 years of age, problems of low body mass, GERD, bowel incontinence, low back pain, and anxiety/depression had improved. The individual felt these changes were largely attributed to the continued participation in the exercise program. He continued with the

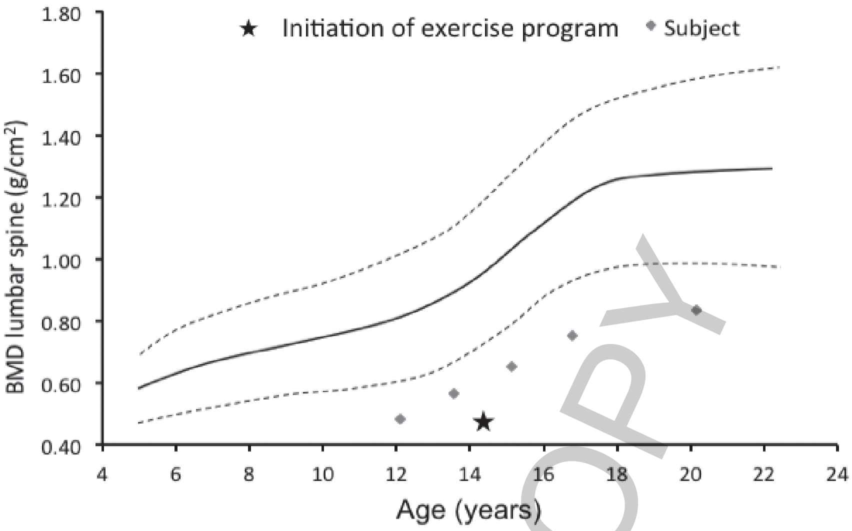

Fig. 1. A comparison of bone-mineral density between "our case" and the data from van der Sluis et al. [19] of DXA results from white boys, with the dotted lines representing $\pm$ 2 SDs.

exercise program described above, and was enrolled in university full time. Endocrinology team reported lumbar spine BMD was Z-score of -2.6, and total right hip BMD Z-score of -2.2. Spinal fusion was no longer a consideration, as it would interfere with his exercise program. Endocrinology reported an interval increase in bone over time in hips and spine. Areal BMD (aBMD; g/cm^2) increased over time, following a similar trajectory as peers without CP (Fig. 1) [19].

2. Discussion

A young adult with severe motor disability as a result of CP and at high risk for fracture [5] was able to participate in an intense exercise program for over 6 years without injury. The individual and his rehabilitation team noted improvements in his GI health, reflux, weight status (increased), sitting mobility, low back pain (reduced), bowel regularity, energy level (higher), and anxiety/depression (reduced) as the result of his commitment to exercise.

Exercise pre-puberty maximizes the response of bone to exercise. In this case report, exercise was initiated post-puberty. If exercise was initiated at an earlier age, bone outcomes may be more compelling. In this report, the impact of exercise on bone health is difficult to separate from the effects of growth. However, it is remarkable that the individual continued on a positive trajectory for gaining bone mass despite severe gross motor impairments. Interval Z-score changes cannot be reported due to changes in DXA machines and reference populations. Yet, an interval increase in bone was demonstrated and overall improvements in Z-scores at the spine and hips occurred over the years. This is of note, as children who are GMFCS level IV-V often lose bone during adolescence [1] DXA is a two-dimensional measure of bone, and changes in bone strength were not directly measured. This case study points to the need to use three dimensional measures, such as PQCT, to evaluate the effects of exercise on bone health.

Total hip aBMD is usually not reported in children due to variability in growth, difficulties with positioning, and lack of reproducibility [20] The International Society for Clinical Densitometry recommends measuring the distal femur in patients with disease that may affect the skeleton, such as CP [15] The distal femur is a common fracture site [1] in individuals with severe CP, and is a skeletal site with good reproducibility when compared to the proximal femur. There were only a few measures obtained at the distal femur, making it difficult to draw conclusions related to the exercises. However, due to the site specific response of bone to exercise, the individual's exercise program described primarily generated loads targeting the upper extremities and trunk. Thus, the exercises may not have had an impact on the distal femur, a common site of fracture. Future studies should include weighted vests or vibration through pads [21] as other mechanisms to increase bone accrual in the spine and distal femur.

The exercises performed by the individual were of moderate velocity and intensity. The treatment effect to the bone could potentially be increased by dosing strengthening exercises 70–85% of 1RM 6–10 repetitions, 3 sets, 3–4 times per week [22], as recommended by the National Strength and Conditioning Association [23]. Use of bisphosphonates [24] in combination with exercise also has the promise to accelerate bone accrual, though the individual did not use pharmacological interventions other than dietary supplements. The use of bisphosphonates in the growing skeleton is complicated given their direct action on inhibiting the bone resorbing action of osteoclasts. The process of bone resorbtion is an important component of the process of bone modeling during growth, thus it is important to weigh the benefits of combined therapy during the growing years.

Exercise frequency and duration is key; it is a lifestyle. Seated exercises can be performed at home with minimal required equipment. This may help eliminate some barriers to compliance. Exercises can also be performed at a community gym, which may provide opportunities for socialization. The individual's passion about the sport of boxing sparked the interested and sustained the commitment to exercise.

3. Conclusion

Our case-report provides an example of a successful, novel exercise program for an individual with CP who has limited mobility and uses a wheelchair. Seated exercise enabled the individual to improve his overall well-being, pain, GI health, and no fractures were sustained. Patients with severe motor disability and failure to thrive will need to time to develop the ability to participate in speed, resistance, and power training. Guidelines have been established for resistance and power training for children [23] and adaptations for training children with CP [22,25] should be consulted. The exercise program described was not developed by rehabilitation providers, and is under-dosed in terms of resistance and power training [22] Identifying exercises that provide the skeleton with sufficient load to generate adaptations in structure and mass is difficult for individuals who are unable to stand unassisted. Yet, the seated upper extremity resistive and power training, combined with punching bag work show potential as an innovative way to load the spine.

Maintaining or augmenting bone health of the spine and femurs in childhood and adolescence can mitigate risk for deformity and pain in adulthood. Future research that includes a longitudinal investigation bone response to novel exercise regimes in a larger cohort will yield more detailed information about the role of exercise in optimizing bone health in individuals with moderate to severe CP.

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Conflict of interest

The authors have no conflict of interest to declare.

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