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Special Issue

Addressing muscle performance impairments in cerebral palsy: Implications for upper extremity resistance training

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ABSTRACT

Study design: Case study and literature review.

Introduction: Muscle performance consists of not only strength but also muscle power, rate of force development, and endurance. Therefore, resistance training programs should address not only the force-generating capacity of the muscle but also the ability to produce force quickly.

Purpose: To discuss the National Strength and Conditioning Association's resistance training guidelines for youth as specifically related to optimal dosing for muscle strength versus muscle power. Dosing parameters of frequency, volume, intensity, duration, and velocity are discussed independently for strength and power.

Methods: We describe how resistance training principles can be applied to the upper extremity in CP through a case study. The case describes an individual with spastic CP, who has a severe motor disability and is non-ambulatory, but has been able to perform resistance training focused on speed, power, and strength.

Discussion: Recommendations to optimize the dosing of this individual's resistance training program are made.

Introduction

Muscle performance represents the overall capability of a muscle to perform work and consists of the elements of strength, power, rate of force development, and endurance. Although muscle weakness has long been considered one of the primary impairments that contribute to activity limitation in children and adolescents with cerebral palsy (CP), other aspects of muscle performance have received far less attention. Recent evidence suggests that other aspects of muscle performance, such as muscle power and rate of force development, are more impaired than strength and are related to activity limitations and functional performance.[1–3] These concepts will be discussed in this review.

Muscular strength refers to the maximum amount of force or torque that a muscle can generate while weakness refers to a deficit in strength. Lower extremity muscle weakness is pervasive in CP with strength deficits reported between 40% and 60% on average as compared to age-matched typically developing children.[4,5] In addition, children with CP who are weaker tend to walk slower and have lower measures of gross motor function.[6,7] Significant upper extremity and hand weakness has also been reported in children with unilateral or hemiplegic CP, with upper extremity and hand strength positively correlated with both unimanual and bimanual abilities.[8–11] Because of the documented associations between strength and function in children with CP, muscle strengthening has become a standard component of therapeutic interventions. However, increases in strength as a result of strength training are not always associated with the desired improvements in functional abilities.[12,13]

Despite the focus on muscle strength in past years, other measures of muscle performance must also be considered in the context of the performance of functional activities. Muscle power is the product of force and the velocity at which the force is produced and can be described as the ability to generate the greatest amount of force as fast as possible. While strength is only concerned with maximal force or torque, power involves both strength and the velocity of the movement. From the force-velocity curve, we know that less force can be produced concentrically at higher speeds as compared to slower speeds. However, in children with CP the ability to produce torque at higher speeds is even more impaired than those without neurological injury.[14] Many daily activities, such as transfers, walking up steps, or moving from sitting to a standing

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position do not require maximal muscle strength. Rather, these activities require force to be generated quickly. We measured knee extensor strength and power in a cohort of ambulatory children with CP and age-matched typically developing children during the performance of an isokinetic test. Peak torque, as a measure of strength, was 64% of typically developing children whereas muscle power was only 18% of the typically developing cohort.[3] We recently showed that after 24 sessions of velocity training for muscle power, children with CP improved their peak power production and were able to walk faster and for further distances, whereas those who underwent the same number of sessions of traditional strength training did not.[2] This discrepancy may partially explain why children who get stronger (rather than more powerful) may not always improve their functional abilities.

Rate of force development (RFD) is an important time-dependent measure of muscle performance that is intimately related to muscle power. RFD is the rate at which force is developed. RFD is typically calculated in the first 200 ms of muscle contraction and represents the magnitude of acceleration in the initial phase of movement.[15] We tested knee extensor RFD during an isometric task in children with CP and age-matched typically developing controls. On average, RFD was only 30% of the typically developing group as compared to strength, which was 50% of typically developing. Further, we found that knee extensor RFD was a better predictor of transfer abilities and sports and physical functioning as compared to strength.[1] This is not surprising, as RFD becomes especially important when force is required to be generated rapidly at the initiation of the movement or during movements with limited range of motion.

Muscle endurance refers to the ability to sustain force over repeated muscle contractions. Muscle fatigue, as the converse of endurance, is measured as the decline in force or torque over repeated contractions. This is not to be confused with self-reported or perceived feelings of generalized fatigue, which may be related to various biochemical, cognitive, emotional, or physical processes. Despite the other muscular performance impairments described previously in children with CP, children, adolescents, and even adults with CP have been repeatedly shown to have similar or even greater muscle endurance than typically developing children in both upper[16] and lower extremity[17–20] muscle groups. In fact, lower functioning children and adolescents with CP who are marginal ambulators have greater muscle endurance than higher functioning ambulatory children with CP.[17] Therefore, muscle endurance is generally not impaired in individuals with CP. Rather, the crux of the issue is that a lower force-generating capacity means operating at a higher percentage of maximal strength during the performance of daily activities, which may lead to an increase in the relative effort and thus, the perceived effort of the task.[17]

In summary, individuals with CP experience significant impairments in muscle performance that are directly related to functional abilities and activity limitations. Muscles of the extremities in children with CP are weak and slow to generate force, yet are highly endurant. Therefore, it is recommended that training protocols target the force-generating capacity of a muscle and the ability to produce force quickly, rather than focusing on training for endurance.

Dosing guidelines for resistance training

Resistance training is a general term that is used to refer to all types of resistance exercise training, such as strength training, power training, and plyometrics, among others.

Despite the equivocal results of the effect of progressive resistance training on function and mobility, resistance training has been shown to produce strength gains in children and adolescents with CP.[12,13,21] Muscle plasticity, including muscle hypertrophy, has been demonstrated in youth with CP in response to resistance training as well as associated neural adaptations.[2,19,22] The degree of strength gains is somewhat variable due to the heterogeneity of subject participants, including severity levels (i.e., Gross Motor Function Classification System [GMFCS] levels) and ages, types of exercises, targeted muscle groups, and varying "dosing" parameters of the intervention. In this context, dosing refers to the delivery of a therapeutic agent in a specified manner. Specifically, we will refer to the recommended guidelines of the National Strength and Conditioning Association (NSCA) for resistance training in children and adolescents who are developing typically throughout the paper.[23] Although specific guidelines for children with CP have not been developed, the NSCA guidelines are based on sound evidence and physiological principles of resistance training specifically for children and adolescents that are safe and effective. The dosing parameters that will be discussed are *frequency, volume, intensity, duration*, and *velocity*. The number of training sessions per week is referred to as *Frequency*. *Volume* is the amount of work performed in a single session and is typically referred to as the number of sets and repetitions. *Intensity* refers to the load or weight that is used and is typically represented as a percentage of 1 repetition maximum (1RM). *Duration* is the total length of the training program. *Velocity* refers specifically to the velocity or cadence at which a strengthening exercise is performed and has implications for the type of muscular adaptations that can occur. Other factors of importance are adequate supervision, progression, types of exercises, rest periods, warm up, and age considerations. In this article we will describe resistance training guidelines for muscle strength and power specifically.

Strength training

The recommended training frequency for strength training is 2–3 times per week on non-consecutive days to allow for recovery between sessions. Volume is intricately linked to intensity, which is typically represented as a percentage of 1 repetition maximum (1RM). The recommended guidelines for volume and intensity are 3 sets of 6–10 repetitions at 70–85% of 1RM with a novice beginning at a slightly higher repetition range (10–15 repetitions) and lower intensity to develop proper technique before progressing to the optimal range. 1RM testing has been shown to be safe and feasible in children (also see Faigenbaum et al[24] for details on how to perform 1RM testing). However, if 1RM testing is not performed, a simple approach using the repetition range can be utilized. Through trial and error, you can determine the maximum load that can be lifted for the desired number of repetitions; for example 6–10 repetitions is equivalent to 70–85% 1RM. If the load is correct, the lower end of the range should be able to be lifted with proper form but no more than 2 repetitions above the upper end of the range before fatigue and loss of form sets in. The load should be progressed and adjusted as needed throughout the training program to maintain the target number of repetitions. A rest period of 1 min between sets is believed to be sufficient for children and adolescents although 2–3 min may be required depending on the intensity, skill level, and activity.[23,25] The recommended duration of the training program is a minimum of 8 weeks with a recommended range of 8–20 weeks. For traditional strength training, controlled to moderate movement velocities are recommended.[23]

Power training

Power training refers to a type of training that maximizes both strength and velocity of movement, sometimes referred to as "explosive strength". Power is defined as the product of force times