Introduction to Cerebral Palsy and Exercise

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All Americans should engage in regular physical activity at a level appropriate to their capacities, needs, and interests. All children and adults should set and reach a goal of accumulating 30 minutes of moderate-intensity physical activity on most, and preferably all, days of the week. Those who currently meet these standards may derive additional health and fitness benefits by becoming more physically active or including more vigorous activity (NIH Consensus Statement, December 18-20, 1995).

There is no longer any doubt that moderate to vigorous levels of physical activity confer immense benefits to one's health. Since the seminal work of Morris and colleagues in the early 1950s, there has been a plethora of research, documenting the benefits of physical activity in reducing morbidity and mortality. In the past three years, this influx of research has led to reports on the health benefits of physical activity from the Surgeon General, National Institutes of Health, and American College of Sports Medicine.

Dovetailing with this fitness movement has been the increased visibility of persons with disabilities in American society. This strong disability rights movement led to the passage of three major laws addressing the rights of persons with disabilities: the Rehabilitation Act of 1973, the Individuals with Disabilities Education Act, and the Americans with Disabilities Act. These laws guaranteed that Americans with disabilities would not be discriminated against in entities receiving federal financial assistance, in schools, in the workplace, and in other public settings, and have helped dismantle some of the common myths associated with persons with disabilities. Despite all the emphasis on physical activity and health over the last three decades, information on guidelines for exercise for persons with disabilities in general, and those with cerebral palsy in particular, is scarce. This was highlighted in a 1996 paper by Rimmer, Braddock, and Pitetti:

The benefits of physical activity and physical fitness have become one of the more popular topics in media circles, with findings from new studies being reported on the evening news, radio talk shows, and in newspapers and magazines around the country. But despite all this publicity, the message seems to be reaching only a small percentage of Americans. Much of the rest of the country remains sedentary, and despite knowing very little about the physical activity habits of persons with disabilities, it is generally accepted that they are at the forefront of this sedentary existence.

There is a pressing need for the public health community to begin to develop exercise guidelines for persons with disabilities, and for consumers to use this information to become more involved in maintaining their health and well-being.

A Brief History of Therapy in the Treatment of Cerebral Palsy

Bower published a comprehensive review that traced the history of rehabilitation and cerebral palsy from the early 1900s to the present. She noted that Phelps was one of the first clinicians to treat patients with cerebral palsy in the 1930s, followed by Peto and Bobath, who became
interested in cerebral palsy a few years later. The major developments in the use of physical therapy in the treatment of cerebral palsy, however, didn't occur until the 1950s. This was largely due to the decline in the incidence of poliomyelitis after the Salk vaccine was discovered, and the shifting of research dollars and therapeutic techniques to persons with cerebral palsy.

Bower's description of the major therapeutic approaches to the treatment of cerebral palsy over the past 50 years is briefly summarized below.

Phelps, an orthopedic surgeon, recommended 5 years of institutionalized therapy from a team approach (physical, occupational, speech and other therapies). He described five different categories of cerebral palsy. His work included the use of motion pictures to describe children and evaluate the effectiveness of treatment. He also endorsed tenotomies (surgery on individual muscles). Paine researched the work of Phelps in 1962 and reported that children with mild spastic hemiplegia improved with and without treatment, and that Phelps' treatment strategies were not effective for children with athetosis. The treatment proposed by Phelps did not change whether or not a child would need surgery. The work of Rood was based on afferent sensory stimulation, but no empirical research has ever been carried out on the efficacy of this therapy.

Vojta, a German neurologist, combined the techniques of Fay, Rood and Kabat. In 1981, research was carried out on one subject with cerebral palsy whose subluxed hip was reduced after 3 years of treatment. In 1984, Kanda looked at Vojta's work with 29 subjects with cerebral palsy. Eight were children with spastic diplegia who had gotten treatment early in their lives, and 21 children with spastic diplegia were treated several months later. All walked by the age of 3. The children who were treated earlier seemed to have an improved gait pattern compared to the children treated later. Vojta also reported on his own work but there are disputes concerning how many of the 207 infants he wrote about (who supposedly became "normal" in mental and motor performance) were children with cerebral palsy.

In 1991, Mayo studied one of the most widespread therapeutic techniques used to treat children with cerebral palsy, the Bobath or neurodevelopmental approach (NDT). Started in the 1940's by Karel and Berta Bobath, this treatment was based on the view that cerebral palsy results from interference with development of normal posture against gravity. The brain lesion leads to the loss of inhibition of abnormal primitive reflexes. Mayo examined the effectiveness of NDT and did not find this technique to be any better than other forms of physical therapy. Wright and Nicholson researched Bobath's work and concluded that there were no differences between children treated with the Bobath method compared to children who received no treatment. The one exception was the ability of children with quadriplegia to roll.

In summarizing her findings, Bower noted that although each of the above methods have been used for decades in treating children with cerebral palsy, there is very little scientific evidence to prove that any one therapy is more or less effective in improving the long-term function of children with cerebral palsy, and that often therapy continues when it may no longer be needed. She noted that "research needs to be undertaken by clinical scientists to assess the relative merits of the various approaches of therapy. Research methodologies used in psychology and the social sciences may well prove to be more useful for this purpose than those used in traditional medical research."
In 1988, a classic study by Palmer and coworkers entitled, "Effects of Physical Therapy on Cerebral Palsy," and published in the highly respected New England Journal of Medicine, investigated two early intervention programs in 48 infants with mild to severe spastic diplegia (12 to 19 months of age). One intervention involved neurodevelopmental therapy and the other intervention was a published infant stimulation program called Learningames. The investigators found that there was no motor, cognitive, or social advantage for infants receiving physical therapy after six and 12 months of treatment, and that trends favored the infant stimulation program. More frequent contact between therapist and patient may have been necessary to make physical therapy more beneficial to infants with cerebral palsy, but if so, this would require higher costs. The investigators concluded with the following statement:

"This clinical trial offers no support for the idea that neurodevelopmental physical therapy is a preferred intervention in infants with mild to severe spastic diplegia. Although it is possible that there are longer-term benefits of physical therapy or benefits in domains not reported in this study, the goal of improved motor development was not achieved in infants receiving physical therapy as compared with infants receiving infant stimulation. Furthermore, physical therapy applied earlier offered no advantage over physical therapy applied six months later. The findings underscore a fundamental issue in developmental pediatrics and public policy affecting developmentally disabled children: the immediate and long-term effectiveness of traditional interventions must be examined critically. Alternative, less costly outcomes may improve function (p. 807)."

In 1995, Graves reviewed the literature on therapeutic methods for cerebral palsy and came to a similar conclusion:

"In reviewing these methods it becomes clear that while all have their zealous proponents, the methodology of evaluation studies is often flawed and the results are inconclusive. Again the call is often made for more and better studies, but the reality is that these methods have had several decades to provide proof of efficacy and none has been forthcoming. Significantly, there has been little or no attention to the negative effects of therapy (p. 26)."

Graves went on to say that although "...therapy does not lead to dramatic improvements in the neurological status of children with cerebral palsy, therapists have an important role in helping families understand how to work with their children in a physical and social setting."

In an extensive review of therapeutic techniques for persons with cerebral palsy, Bleck wrote: "after half a century of sincere and intense effort by professionals to 'treat' cerebral palsy, most now acknowledge that these remedial efforts have been unsuccessful in achieving function. Perhaps it is time to give up trying to 'cure' the neurological deficits by remedial methods, stop looking for positive studies, and get on with the task of helping children and their families."

Despite periodic calls for scientific inquiry into the effects of physical therapy in the treatment of children with cerebral palsy, there are only a handful of clinical trials in the literature that have examined the efficacy of physical therapy. As a result of small, heterogeneous samples, substantial attrition among subjects, and nonrandom assignment of treatment, it is difficult to interpret what are the most effective treatment strategies for improving the motor performance in persons with cerebral palsy. Fetters and Kluzik noted that "this lack of scientific evidence of treatment effectiveness is true for many types of physical therapy for children with cerebral palsy."
This cursory review of the literature on cerebral palsy and therapeutic techniques provides a strong incentive for the Task Force to develop new intervention strategies that will prove useful in the overall physical, psychological and social development of persons with cerebral palsy. Clearly, we must establish a more ecological approach to treatment and must develop safe and effective exercise guidelines for persons with cerebral palsy that can be implemented in community-based fitness settings.

**Exercise Literature on Cerebral Palsy: Resistance Training**

Research has shown that resistance training improves neuromuscular function, which in turn, improves overall function in daily activities and motor performance. As a person ages, the need increases for adequate levels of strength to continue performing activities of daily living (ADLs) independently. Many research studies on older populations have noted that as strength declines, so too does the ability to perform ADLs, thus compromising the individual's quality of life.

McCubbin and Shasby studied the effects of a resistance training program on elbow extensor strength in 30 children and adolescents with different degrees of cerebral palsy who ranged in age from 10 to 20 years. Subjects were matched on type and severity of cerebral palsy using the classification system employed by the National Association of Sport for Cerebral Palsy (now called the National Disability Sports Alliance). The investigators used two different training protocols: isokinetic exercise and repetitive movement exercise without resistance. Subjects in the control group continued their usual therapy in their respective schools. The treatment protocol consisted of exercising the tricep extensor group with three sets of 10 maximal speed repetitions, three times per week for six weeks. Subjects in the repetitive exercise group (no resistance) followed the identical training program as the isokinetic exercise group, except that the repetitions were completed without any resistance. The investigators found significant differences in speed of movement and time rate of torque development in the isokinetically trained group.

McCubbin and Shasby recommended further research: matching subjects on more variables (age, sex, etc.); collecting data over several repeated measures for both movement time and torque; varying the speed of isokinetic training; and using a single subject design to compare the effects of isokinetic training on the various types of cerebral palsy.

The application of resistance training throughout the full range of motion, coupled with the emphasis of rate of movement, produced a training effect in individuals with cerebral palsy similar to that found in exercise programs in non-handicapped subjects.

Holland and Steadward studied the effects of resistance and flexibility training on seven elite athletes with cerebral palsy. Their study also showed increased strength in all athletes in elbow flexion and extension. They also found quadriceps/hamstring improvement for the three athletes who could walk. Flexibility showed improvement in active and passive range of motion, but active showed a greater increase. Fine motor tasks improved in six of the seven athletes. Their only caution was that all participants should stretch the major muscle groups of the upper and lower body before engaging in resistance exercise. They also noted that in their subjects, the wrists and ankles seemed to display less range of motion because these joints are rarely stretched.
Holland and Steadward noted that "athletes with cerebral palsy can participate in intense strength training programs without experiencing detrimental effects in flexibility and spasticity."

Olney and colleagues evaluated the work and power of major muscle groups in the affected limbs of 10 children with spastic hemiplegia. Cinematographic film and force-plate data were used to calculate the positive and negative workload around each joint. The investigators found that the force produced by the ankle plantar flexors during slow and normal walking speeds was different compared to healthy adults. In healthy adults, the ankle plantar flexors contribute nearly 66 percent of the total concentric work; the hip flexors and extensors are responsible for approximately 25 percent of the total concentric work; and the knee extensors the remainder. In children with cerebral palsy, the ankle plantar flexors provided only 33 percent of the total work of the affected limb.

Olney and coworkers concluded that the ankle plantar flexors on the affected side of children with spastic hemiplegia are severely deficient in generating power during walking, which resulted in greater amounts of work being done by muscle groups of the hip. They recommended that good range of motion at the ankle should be emphasized so that muscular contraction can be effective in generating power. In developing strength programs for persons with cerebral palsy, it is important to assess individual muscle groups to determine any asymmetrical weakness that may impose a greater burden on walking.

King et al. researched the feasibility of improving gait in children with cerebral palsy using a hip-extensor tricycle (with added weights). Their initial hypothesis was that if they could improve hip extensor strength, gait would improve. After working with their subjects on this specially adapted tricycle for 10 weeks, they saw no results in strength after testing them in two different ways. However, they did find an improvement in gait.

The specially built hip-extensor tricycle did activate hip-extensor muscles similar to walking, and to a greater extent than a traditional tricycle. The investigators noted that training on a device that promotes an upright movement pattern similar to walking probably improves motor control in gait. Although gait improved, hip extensor strength did not. The researchers used only five children with cerebral palsy. It would be interesting to determine if a similar adult-size tricycle could elicit improved gait in adults with cerebral palsy. Adaptive fitness technology for persons with cerebral palsy is something for the Task Force to consider over this two-day meeting.

In 1994, Kramer and MacPhail studied the relationships among measures of walking efficiency, gross motor ability and isokinetic strength in 17 adolescents with cerebral palsy. They reported that "adolescents with mild cerebral palsy could safely and reliably be tested for knee extensor and flexor strength during standardized isokinetic tests of concentric and eccentric muscle actions." They also reported that isokinetic equipment can be safely used with this population.

Kramer and MacPhail offered several recommendations for future research:

a) Determine if changes in muscular strength are reflected by changes in gross motor ability and walking efficiency;

b) Determine if individuals with cerebral palsy can respond to a strength training program without unwanted side effects; and

c) Evaluate how strength training programs might best be combined with neurological techniques.
The most important finding from the Kramer and MacPhail study was that there was a direct relationship between knee extensor strength and efficient walking and gross motor ability. They believed that lack of strength in the knee extensors could be one reason why adolescents with CP are limited in their standing, walking, running, and jumping activities. They stated that "improvements in muscular strength may be associated with improvements in walking efficiency and functional abilities in this population." There is a strong need to replicate this research on adults with cerebral palsy.

O'Connell, Barnhart, and Parks examined the relationship between muscular endurance and wheelchair propulsion in three children with cerebral palsy. Using a 6-RM test for elbow flexion, elbow extension; shoulder abduction, flexion, extension, internal and external rotation; and a combined shoulder flexion-elbow extension with cuff weights, dumbbells and barbells, their data showed that muscular endurance and both anaerobic and aerobic wheelchair tasks were correlated. They recommended that a muscular endurance program be developed for persons who use a wheelchair for ambulation, since there is a strong association with the ability to push a wheelchair and the amount of muscular endurance that a person possesses. They cautioned, however, that with such a small sample size, more research is needed on specific outcomes of muscular endurance training.

In 1995, O'Connell and Barnhart published a similar study using the same data set to determine if resistance training could improve wheelchair propulsion in pediatric wheelchair users. The three children with spastic cerebral palsy performed resistance exercises three times a week for nine weeks, using cuff weights, dumbbells and barbells. They performed three sets of 6-RM for each movement: elbow flexion and extension; shoulder abduction, flexion, extension, internal and external rotation; and a combined supine shoulder flexion-elbow extension.

Results indicated that progressive resistance exercise training appears to be able to improve muscular strength and wheelchair performance in children with cerebral palsy. However, the small sample size (n=3) and lack of control group warrants caution when interpreting the results. O'Connell and Barnhart did conclude, however, that "consideration should be given to use of a formal resistance training program to enhance and maintain wheelchair propulsion abilities. We may be understressing these children and preventing them from achieving their full physiological potential."

In 1995, Damiano, Kelly and Vaughn studied the effects of quadriceps femoris muscle strengthening on crouch gait in 14 children with spastic diplegia. They wanted to determine if there was a causal link between resistance training and improved gross motor function. The subjects exercised three times a week for six weeks using ankle weights at loads of approximately 65% of maximum isotonic force production. Gait analyses were also performed before and after the study. The investigators found that the subjects were able to increase quadriceps femoris strength with resistance training, and that there was no increase in hamstring muscle force. They concluded: "our study focused on quadriceps femoris muscle weakness as one component of the motor dysfunction seen in children with CP, and utilizing a traditional orthopedic approach rarely recommended with this population demonstrated clinical improvement in strength and ambulatory ability." However, they cautioned that several of the children developed knee hyperextension in mid-stance, which prompted the investigators to recommend the possibility of hamstring strengthening at the same time that the quadriceps are developed.
They made the following recommendation for future research: "Although strengthening is an effective treatment option in CP, more evidence of functional improvements due to strengthening that have a significant impact on the quality of life of these children needs to be produced through the use of motion analysis or other objective outcome measures prior to widespread advocacy of this approach in the clinic."

Damiano, Vaughn and Abel continued their research and examined the muscle responses to heavy resistance training in children with cerebral palsy. They compared their findings to a control group of 25 children who did not have a disability. The investigators found that "all children [with cerebral palsy] who participated in the study had consistent and dramatic strength increases in the quadriceps muscle, with the majority attaining normal strength values. A concurrent increase in the strength of the hamstring muscles was not found. This eliminated the concern that heavy resistance exercise would elicit unwanted muscle activity in antagonist muscles. The researchers also reported that quadriceps strengthening improved "knee extension in terminal swing, as indicated by significantly less knee crouch at initial floor contact and increased stride lengths at free and fast walking speeds."

The investigators made the following recommendations:

a) a more comprehensive lower-extremity strength training program involving several muscle groups might produce greater functional improvements;

b) the biomechanical and physiological implications of weakness and muscle imbalance in spastic cerebral palsy need to be better understood;

c) precise quantification of the pattern and magnitude of the weakness is needed; and

d) there should be "objective" documentation of change produced by interventions that positively or negatively effect strength.

In their most recent study, Damiano and Abel expanded their research to examine the effects within and across two distinct clinical subgroups: children with spastic hemiplegia (n=5) and children with moderate to severe spastic diplegia (n=6). The children ranged in age from 6 to 12 years. The investigators wanted to determine if a resistance training program would increase strength in certain targeted muscles. The untrained muscles were used as a basis for comparison. In the children with hemiplegia, strength changes on the more affected extremity were compared to corresponding muscles on the contralateral extremity. In the children with diplegia, the ipsilateral antagonist muscles were used as the untrained comparison. Eight muscle groups were tested using a hand-held dynamometer.

A secondary purpose of the study was to determine if subjects could achieve functional gains in performance after the resistance training program. Computerized gait analysis was used for this purpose. Subjects were asked to exercise three times a week for six consecutive weeks. Velcro-attached free weights were used, and the load for each muscle was approximately 65 percent of the maximum isometric strength value. Each subject performed four sets with five repetitions in each set at each muscle group.

Results of the study found that in the children with diplegia, there was a 69 percent increase in strength after training in the targeted muscle groups, and in the children with hemiplegia, there was a 20 percent increase. Functional changes were also found for the entire group. Subjects increased their maximal speed during fast walking.

Damiano and colleagues reconfirmed the findings of previous research that resistance training in young individuals with cerebral palsy is safe and effective in improving strength and motor performance: "to our knowledge, there is no research to support the theory that resistance
training increases the recruitment of other muscles that are already overactive or spastic, which would obviously be contraindicated if this were the case."

In their most recent article (1998) on resistance training in children with cerebral palsy, Damiano and Abel concluded that a short-term strength training program demonstrated positive functional outcomes. They also reiterated that the clinical concern that resistance training will cause an "inadvertent strengthening of the spastic antagonist muscle during training" is unfounded.

MacPhail and Kramer tested the effects of isokinetic resistance training on functional ability and walking efficiency in 17 adolescents with cerebral palsy. Their eight-week strength-training program yielded noteworthy results. The adolescents showed significant increases in knee extensor and flexor strength as a result of training. They also reported that the children with diplegia, and one subject with quadriplegia, when given the opportunity to participate in joint-specific muscle strengthening independent of their ability to balance in standing, were able to respond with substantial increases in strength. They concluded that "muscle capability of adolescents with mild cerebral palsy is relatively normal." They found no increased spasticity resulting from the strength training program.

They recommended the following ideas for future research: a) Determine the actual mechanism of strength gains; b) Evaluate the optimal frequency and duration of strength-training programs; c) Investigate the practicality of resistance training for other lower-extremity muscle groups such as the ankle plantar flexors and dorsi flexors; and d) Establish criteria for appropriate selection of subjects who can safely participate in such programs without unwanted side-effects.

"No scientific evidence exists to support the clinical prejudice against strength testing and training for individuals with cerebral palsy or other upper motor neuron disorders. In fact, research findings are accumulating that indicate that children with cerebral palsy are indeed weak, that strength is related to motor function, and that isotonic and isokinetic strengthening programs can result in functional improvements."

Cardiorespiratory Fitness Levels in Persons with Cerebral Palsy

There is considerably less research on the cardiorespiratory fitness levels of persons with cerebral palsy compared to the research that has been completed on resistance training. The brevity of this section is an indication of the strong need for more research in this area.

One of the first investigators to assess the cardiorespiratory fitness levels of persons with cerebral palsy was the Swedish physiologist, Ake Lundberg. The aim of one of Lundberg's earlier studies was to determine the maximal aerobic power of persons with spastic cerebral palsy. Lundberg measured the aerobic power of nine children and five young men with spastic diplegia. Nine children without disabilities and five men without disabilities served as the control group. The degree of disability ranged from slight (no aids to ambulate) to severe (six of the 14 subjects used a wheelchair). All tests were performed on a mechanically braked bicycle ergometer. Results showed that the subjects with cerebral palsy had lower values for heart rate, oxygen uptake, ventilation, and blood lactate concentrations compared to the control group. Physical work capacity at 170 beats per minute was only 50 percent of the non-disabled controls.
In a later study, Lundberg examined longitudinally the physical work capacity and aerobic power in 19 children with spastic diplegia, and compared them to a control group of 12 non-disabled children of the same age and sex. The degree of impairment ranged from slight (no aids required to ambulate, six boys and three girls) to fairly severe (six boys and four girls, eight of whom used a wheelchair). Heart rate, oxygen consumption (VO2), physical work capacity at heart rate 170, pulmonary ventilation, and blood lactate concentrations were measured during submaximal and maximal work on a bicycle ergometer two or three times a year over a six-year period. Levels of fitness (VO2 and physical work capacity) were higher for the control group compared to subjects with cerebral palsy, but over the six-year period this gap did not increase. Interestingly, absolute values for aerobic power and physical work capacity increased from 12 to 18 years in both groups.

In 1990, Fernandez, Pitetti and Betzen evaluated the aerobic capacity of nine ambulatory adults with spastic cerebral palsy and concluded that their cardiorespiratory fitness levels were very poor.

As a follow up to this research, Pitetti et al. developed a cardiorespiratory conditioning program for seven ambulatory adults with spastic cerebral palsy to try to improve their functional capacity (peak VO2). A secondary purpose of the study was to determine if after an 8-week training program, subjects would continue to exercise on their own. Subjects exercised on a Schwinn Air-Dyne bicycle ergometer twice a week for 30 minutes at a work intensity between 40 to 70% of peak VO2. Significant improvements in peak VO2 were achieved at the end of the 8-week program (average improvement was 12%).

The researchers concluded that cardiorespiratory fitness improved in seven adults with cerebral palsy who trained on a Schwinn Air-Dyne for eight weeks. However, once the study ended, only one subject continued to exercise. When developing exercise programs for persons with cerebral palsy, it is important to consider the barriers to exercise and determinants of exercise in this population. The best exercise guidelines in the world will have little impact if substantial barriers (i.e., transportation, cost, medical concerns, etc.) cannot be overcome. However, once the study ended, only one adult continued to exercise. The investigators concluded that the cardiorespiratory fitness levels of adults with cerebral palsy were very low, and suggested a strong need for further research to determine the most appropriate training regimens for improving cardiorespiratory fitness in this population.

**Fitness Testing in Persons with Cerebral Palsy**

**Measuring Aerobic Power (Cardiorespiratory Fitness)**

In 1992 and 1993, Bhambhani and coworkers tested the validity and reliability of maximal aerobic power (VO2) during wheelchair ergometry (WE) and bicycle ergometry (BE) in six wheelchair athletes with cerebral palsy. Although there was no significant difference in aerobic power between WE and BE, the researchers found that there were large intra-individual differences. Higher VO2s were obtained on the WE test in subjects who used a wheelchair as their primary mode of ambulation, while the one subject who did not require any aids to ambulate, performed better on the BE.

In a later study, Bhambhani and coworkers evaluated the anaerobic threshold in 11 adult males with spastic cerebral palsy. They concluded that AT was not valid and reliable in this population, which could have been related to the type of test used (discontinuous), or the rate of lactate diffusion into the blood as a result of variations in muscle spasticity during the test.
The investigators also found that only 5 of the 11 subjects were able to complete a bicycle ergometer test, while all 11 subjects were able to complete the wheelchair ergometer test. This was due to the high level of spasticity in the legs, which prevented adequate hip flexion necessary for pedaling the bicycle ergometer. This is slightly conflicting with Bhambhani's previous study in which he found that the bicycle ergometer was a better testing mode for the one subject who was able to ambulate. However, this subject may have had less spasticity in the legs thus permitting him or her to perform the cycling motion.

Holland and coworkers examined the test-retest reliability of the anaerobic threshold (called the ventilatory threshold [VT] in this paper) and maximal aerobic power in nine adults with cerebral palsy. They concluded that the VT was not an appropriate cardiorespiratory fitness parameter to measure in adults with cerebral palsy, but that VO2 max can be reliably measured in this population.

When testing subjects with cerebral palsy on VO2, it is important to find a modality that allows the person to achieve a maximal performance. For some, this may be the wheelchair ergometer, while for others who have less spasticity in the legs, a better test will be achieved with the bicycle ergometer. The more muscle groups that can be applied during testing, the greater likelihood of a higher and more accurate performance score.

Measuring Anaerobic Power

Tirosh, Bar-Or and Rosenbaum conducted one of the largest studies to date on the anaerobic power of children with cerebral palsy. Sixty-six children aged 5 to 18 years participated in the study. Thirty-eight of the subjects had cerebral palsy, 27 with spasticity, 10 with athetosis, and one with athetosis and ataxia; 28 children had other types of neuromuscular diseases (i.e., Duchenne's). The investigators measured power using the classic Wingate Anaerobic Test. They concluded that the test is highly reliable and reproducible for children with a neuromuscular disease.

Parker, Carriere, Hebestreit, and Bar-Or conducted a follow-up study and evaluated the anaerobic endurance and peak muscle power of 49 children with spastic cerebral palsy, ages 6 to 14 years. Nineteen subjects had quadriplegia, 16 had diplegia, and 14 had hemiplegia. They once again used the Wingate test to measure anaerobic power. The investigators found that the peak anaerobic power and muscle endurance of the upper and lower limbs in children with spastic cerebral palsy was, in their own words, distinctly subnormal.

In 1996, van de Berg-Emons et al., studied the reliability of tests to determine peak aerobic power, anaerobic power and isokinetic muscle strength in 12 Dutch children with spastic cerebral palsy. A secondary purpose was to compare their results to 39 nondisabled children matched on age and sex. Aerobic power was tested with a Monark bicycle ergometer; anaerobic power was measured using the standard Wingate test; and isokinetic muscle strength of the knee extensors and flexors was measured with the Cybex II isokinetic dynamometer. The investigators found that children with cerebral palsy can attain reliable measures on aerobic power, anaerobic power, and muscle strength, but that the higher intra-individual differences seen in the children with cerebral palsy suggest that the tests are "less suitable for children with cerebral palsy than in their healthy peers." Peak aerobic power, muscle strength and anaerobic power were found to be lower compared to the non-disabled children.
The Dutch investigators concluded that peak aerobic power, anaerobic power and isokinetic muscle strength in children with cerebral palsy were below average compared to children without disabilities of the same age and sex. Only three of 12 children (25%) had performance scores that fell within the "normal range" for their age and sex. The investigators noted that possible explanations could be "agonist/antagonist co-contraction, low muscle mass (especially of the fast-twitch fibers), the presence of contractures, detraining, and attention deficits." In any event, it is clear from this research that more emphasis must be placed on improving these fitness parameters in persons with cerebral palsy.

In 1997, van de Woude, et al., reported on anaerobic testing of 67 elite wheelchair athletes, including six athletes with cerebral palsy. The researchers concluded that anaerobic capacity can be reliably measured with a 30-second sprint test in wheelchair athletes, but in athletes with cerebral palsy there was wide diversity in performance that may be related to their level of function. Because of the many different disabilities used in their study, it is difficult to generalize the findings to any one group.

Energy Cost of Walking in Children with Cerebral Palsy

Rose and colleagues conducted three studies on the energy cost of walking in children with cerebral palsy. In their first investigation, they compared the energy cost of using a wheeled walker versus bilateral quad canes in 12 children with quadriplegic or diplegic spastic cerebral palsy, ages 4 to 12 years. For each trial, the child's average heart rate, walking speed and the number of heartbeats per unit distance walked were calculated. In order to account for the variations in speed of each child, an energy cost index was derived based upon the average number of heartbeats per unit distance walked (heart beats per minute divided by meters per minute). The investigators found that in general, the children elicited extremely high heart rates and slow walking speeds during ambulation with the two assistive devices. The mean heart rate with the walkers was 164 bpm, and with the canes, 157 bpm, as compared to 114 bpm for the non-disabled children ambulating without an aid.

In their second study, Rose et al., measured the energy cost of walking in 31 non-disabled children and compared them to 13 ambulatory children with spastic cerebral palsy (hemiplegia or diplegia), ages 7 to 17 years. To be eligible for the study, the subjects with cerebral palsy had to be able to walk on a treadmill with or without using the handrails. The investigators found that the relationship between heart rate and oxygen uptake at different walking speeds was linear in both the nondisabled subjects and the subjects with cerebral palsy.

In their third study, Rose et al. used the same data set as in their previous study (18 nondisabled children and 13 children with spastic cerebral palsy) to further determine if heart rate provided an accurate estimate of energy expenditure. An energy expenditure index (EEI) was calculated based on oxygen uptake and heart rate. The formula for EEI was heart rate minus resting heart rate, divided by walking speed. Values were plotted at different walking speeds. The investigators concluded that heart rate is an accurate indicator of energy expenditure in children with cerebral palsy and can be used in clinical settings to evaluate the energy cost of different locomotor activities.

The work of Rose and colleagues involving children with cerebral palsy has essentially demonstrated that there is a linear relationship between heart rate and oxygen consumption similar to what is observed in persons without disabilities. Therefore, an exercise prescription based on heart rate intensity formulas should be accurate for persons with cerebral palsy.
Cerebral Palsy and Sport

Sherrill has been involved in the development and promotion of sport for individuals with cerebral palsy for many years. In her excellent textbook, Adapted Physical Activity, Recreation and Sport, she notes that there are two organizations that promote sports for persons with cerebral palsy: Cerebral Palsy International Sports and Recreation Association and the United States Cerebral Palsy Athletic Association. There are eight classifications in USCPAA sports: Classes 1-4 are non-ambulatory and Classes 5-8 are ambulatory. The classifications are broken down further by specific level of function and have some potential implications for developing general exercise guidelines for persons with cerebral palsy.

A comment made to Dr. Ken Richter at the 1988 Paralympics in Seoul, Korea emphasized the social value of sport for persons with cerebral palsy: "I have a son who is 21 years old. Even my neighbors did not know that he exists because I was ashamed that he has cerebral palsy. Now with the Paralympics I can go out in public without shame."

In an excellent paper written by Richter, Gaebler-Spira and Mushett, the importance of sport for persons with cerebral palsy was emphasized from both a physical and psychological standpoint. Using anecdotal information from the 1988 Paralympics in Seoul, Korea, the authors noted that sport is an excellent medium for changing society's attitudes towards persons with cerebral palsy. They concluded by calling for the medical community to promote sport and exercise in their patients with cerebral palsy.

Cerebral Palsy and Health

When developing exercise guidelines for persons with cerebral palsy, it is important to consider secondary health conditions that may impact or limit a person's ability to participate in certain physical activities. One of the pioneers in the area of health and cerebral palsy is Dr. Margaret Turk. In a recent article, Turk and coworkers evaluated the health status of 63 women with cerebral palsy residing in the community. The secondary conditions found in this sample that may have an impact on an exercise prescription were as follows: pain, musculoskeletal deformities, and bowel and bladder problems. The associated conditions reported in the sample were: seizures, mental retardation, learning disabilities, and sensory disorders.

Turk and coworkers reported that pain was found in 84 percent of the sample and limited the activities of 56 percent of the sample. The most common sites for pain were the head (28%), back (26%), and arm (23%). Musculoskeletal deformities were reported in 59 percent of the women. Seventy-five percent had some type of contracture, with the most common sites being the ankle, neck and hip. Forty percent of the sample had at least one hip deformity and 53 percent had kyphosis or scoliosis. Leg-length discrepancies were seen in 44 percent of the women. Fifty-nine percent reported having both a hip and back deformity. Bowel and bladder problems were reported in 56 percent and 49 percent of the sample, respectively. Surprisingly, 83 percent of the sample reported engaging in at least one common physical activity, including swimming, walking, use of exercise equipment, and weight lifting. However, there were no data reported on the qualitative aspects of the exercise.

In what will surely be one of the pioneering studies on the health status of women with cerebral palsy, Turk and coworkers provide some valuable input on secondary and associated conditions that will be helpful to the Task Force in preparing exercise guidelines for persons with cerebral palsy.
with cerebral palsy. The following comments related to physical activity should also be considered in exercise guideline development over this two-day meeting:

"The significant association of the ability to walk and participation in physical activity, and of wheelchair use and physical activity, show the importance of physical function in exercise-based health promotion activities. These findings suggest that the use of mobility devices and other adaptive equipment are important considerations in designing exercise interventions. The significant association between stretching and/or doing ROM exercises and hip deformity may be suggestive of the therapeutic need for stretching in the management of a hip deformity. Similarly, the significant relation between musculoskeletal deformity and engagement in physical activity, such as with back deformity, may indicate the importance of general physical activity as a therapeutic intervention for certain musculoskeletal deformities."

Other health concerns found in persons with cerebral palsy were highlighted in a report edited by Turk, Overeynder, and Janicki entitled, "Uncertain Future - Aging and Cerebral Palsy: Clinical Concerns." In this report, it was noted that musculoskeletal complaints are the most significant problem experienced by adults with cerebral palsy. The pain often originates from soft tissue injuries in muscles, tendons, ligaments, or nerves. The authors noted that the pain may be related to the "way a person performs an activity and often may be the result of repetitive movements over time." Fatigue was also listed as a recurrent complaint of adults with cerebral palsy, and that sometimes pain and fatigue are experienced together.

**Osteopenia and Cerebral Palsy**

Although Turk and coworkers found that only 5 percent of adult women with cerebral palsy were reported to have osteoporosis, three other studies found high levels of osteopenia among children with cerebral palsy. In the first study, Henderson et al. reported levels of bone mineral density on 139 children (mean age = 9+3.6 years, 3 to 15 years) with spastic cerebral palsy. Bone mineral density was measured with dual-energy x-ray absorptiometry (DEXA) and compared to 95 age-matched subjects without disabilities. The investigators found that although bone mineral density varied greatly among subjects, on average the children with cerebral palsy were one standard deviation below the age-matched group without disabilities.

In the second study, Shaw et al. measured the bone mineral density in the lumbar spine of 9 children who were non-ambulatory with cerebral palsy, ages 2 to 13 years. Subjects were compared to an age and sex-matched control group of children without disabilities. All of the children with cerebral palsy exhibited a severe reduction in bone mineral density.

In the third study, Lin and Henderson found reduced muscle mass, bone mineral content, and bone mineral density in the affected limb of 19 children with spastic hemiplegia. Lean muscle mass was reduced by 15 percent and bone mineral density by 6 percent in the affected limb of children with cerebral palsy compared to the unaffected limb. The researchers noted that further research is needed to determine if these reductions can be altered through weight-bearing activities.

**Muscle Histopathology in Cerebral Palsy**
In 1996, a group of Japanese researchers studied the muscle fiber composition of children and adolescents with cerebral palsy, ages 6 to 18 years. During achilles tendon lengthening operations, the researchers took muscle biopsies from the gastrocnemius muscle on the operated side. They reported that muscle fiber composition was substantially different in this group compared to non-disabled subjects. While Type-1 fiber percentage is normally around 45 to 57 percent, Type-1 fiber distribution in the subjects with cerebral palsy was 68 to 96 percent and Type-2 fiber distribution was reduced in number. This may provide some evidence as to why power-related activities are deficient in persons with cerebral palsy. Normally, the Type II fast-twitch fiber is needed for anaerobic performance. Future research should evaluate the possibility of altering fiber type arrangement through high-intensity, power-related activities in persons with cerebral palsy.

**Future Recommendations**

Along with these guidelines, it is also important to stimulate discussion on future research issues that will encourage other investigators to develop a better understanding of the fitness needs of persons with cerebral palsy. In a recent article, Rimmer, Braddock and Pitetti emphasized the need for more exercise-related research on persons with disabilities:

*There is a pressing need to study the activity patterns and physiological responses to exercise in persons with disabilities. The biggest challenge ahead for exercise scientists will be to find ways to get people with disabilities more involved in physical activity, particularly persons with mental retardation, Alzheimer's disease, stroke, cerebral palsy, spina bifida, spinal cord injured, autism, and traumatic brain injury. If the discipline of exercise physiology is going to have an impact on the lives of Americans with physical and mental disabilities, questions concerning exercise testing and exercise prescription guidelines, and barriers to participation in physical activity and fitness programs by specific groups of individuals with disabilities, must be addressed in future research. (Rimmer, Braddock, & Pitetti.)*

A few research recommendations are listed below:

1. Most of the research on resistance training and cerebral palsy has focused on children and adolescents. There is virtually no research on functional outcomes of resistance training in middle-aged and older adults with cerebral palsy.
2. Longitudinal studies demonstrating the effects of training in persons with cerebral palsy are direly needed. Aside from one Swedish study with children completed over a decade ago, there are no fitness intervention studies in the literature that have lasted more than two months.
3. The relationship between physical fitness and health outcomes in persons with cerebral palsy must be studied. We know very little about the long-term impact of exercise on the overall health (i.e., body fat, blood lipids, blood pressure, functional mobility) of persons with cerebral palsy.
4. More research is needed on flexibility training. Amazingly, the exercise literature is void of training studies with persons with cerebral palsy.
5. Body composition data on persons with cerebral palsy are also absent. Research using field-based (i.e., skinfolds) and laboratory instruments (i.e., DEXA) to assess body composition is needed.
6. Most of the fitness literature has been completed on children with cerebral palsy. A greater emphasis must be made to study young and older adults with cerebral palsy.
7. Research is needed to evaluate the determinants of exercise and barriers to exercise in persons with cerebral palsy.
8. Training modalities that are optimal for improving fitness in persons with cerebral palsy must be explored. Also, accessibility of fitness equipment and fitness programs for a wide range of disabilities must be examined.

About the Author

James H. Rimmer, Ph.D., is a Professor in the Department of Disability and Human Development at the University of Illinois at Chicago. For the past 20 years, Dr. Rimmer has been developing and directing exercise programs for persons with disabilities. He is the sole author of the textbook, Fitness and Rehabilitation Programs for Special Populations, and has published many peer-reviewed journal articles and book chapters on various topics related to physical activity, health promotion and disability. Dr. Rimmer is currently directing a federally funded Center on Health Promotion Research for Persons with Disabilities, which is examining the effects of exercise and health promotion on persons with stroke, diabetes, arthritis, spinal cord injury, and Down syndrome. He is also the director of the National Center on Physical Activity and Disability, which collects, synthesizes, and disseminates information on physical activity and disability. Both of these grants are funded by the Centers for Disease Control and Prevention. Dr. Rimmer is one of four principal investigators in the Midwest Royal Center for Health Maintenance, which is a grant funded by the National Institute on Aging to assess long-term exercise adherence among persons with disabilities, and is a co-investigator in the National Institute on Disability and Rehabilitation Research, Rehabilitation Research and Training Center on Aging with Mental Retardation at the University of Illinois at Chicago. He is a member of the Scientific and Medical Advisory Board for LifeFitness Academy.

Organizations

1. Cerebral Palsy - International Sports and Recreation Association: Bad Neuenahr, Germany
2. Centers for Disease Control and Prevention: Atlanta, Georgia
3. National Institute on Aging: Bethesda, Maryland
5. Life Fitness: Schiller Park, Illinois
6. United Cerebral Palsy: Washington, District of Columbia

Books

Journals


Reports