Aquatic exercise for children with cerebral palsy

Review

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Exercise for children with cerebral palsy (CP) is gaining popularity among pediatric physical therapists as an intervention choice. Exercise in water appeals to children with CP because of the unique quality of buoyancy of water that reduces joint loading and impact, and decreases the negative influences of poor balance and poor postural control. In this paper, research of land-based exercise and aquatic exercise for children with CP is reviewed. Clinically relevant considerations for aquatic exercise programming for children with CP are discussed.

Exercise refers to planned structured activities involving repeated movement of skeletal muscles that result in energy expenditure and seek to improve or maintain levels of physical fitness.[1] Exercise is increasingly being considered as an intervention therapy for children with cerebral palsy (CP) to improve levels of muscle strength,[2] aerobic capacity,[3] and gross motor function.[4] Forms of exercise have been components of therapy programs for children with CP in the past;[5] however, exercise was often avoided because of concern about the effect of such effort on muscle spasticity and children's movement patterns.[6] Several factors have contributed to a recent shift in perspective about the use of exercise in children with CP. Studies evaluating the effect of exercise on children with CP report no adverse effect on patterns of movement,[7,8] flexibility,[8,9] or spasticity.[10] The World Health Organization *International Classification of Disability, Function and Health* (ICF)[11] has influenced therapy programs towards moving away from a 'consequences of disease' classification to one that acknowledges multiple factors contributing to a child's health. The philosophy of the ICF has resulted in a shift of therapeutic focus from one of preventing disease to one of maximizing overall health. In addition, the dynamic systems theory of motor development explains the acquisition of motor skill as a dynamic and self-organizing process resulting from the interaction of multiple subsystems within the child, the environment, and the task.[5,12–14] Approaches based on the principles of the dynamic systems theory emphasize the child's active and volitional role in therapy and target subsystems within the child (e.g. muscle strength and cardiovascular fitness) in addition to the central nervous system.[15,16] The dynamic systems theory has encouraged therapists to consider the influence of fitness parameters, such as muscle strength, cardiovascular fitness, and flexibility, on the movement abilities and participation levels of children with CP.[17] Exercise for children with physical disabilities is also among key strategies identified in national and international health promotion initiatives,[18,19] and is considered instrumental in reducing the risks of factors such as fatigue,[20,21] decreased cognitive attention,[20] and decreased working efficiency[22] among individuals with CP. Because of these factors, exercise

as therapy is receiving increased attention.

Research evaluating the effects of exercise for children with CP has focused primarily on land-based exercise.[4,7,17,23–29] Exercise in water may be suitable for children with CP, particularly for those with significant mobility impairments because the negative influence of poor balance, poor postural control, and excessive joint loading are reduced in water.[30,31] In this paper we briefly review the research into land-based exercise for children with CP, and then review the literature on aquatic exercise and discuss its potential as an exercise option for this group of children.

Exercise for children with CP

EXERCISE VERSUS GENERAL PHYSICAL ACTIVITY

One challenge of existing fitness studies involving children with CP is the lack of distinction between general physical activity and exercise. Although studies evaluating a wide variety of forms of general physical activity for children with CP exist,[3,4,7,17,23,25,26,28,32–35] they do not all satisfy the criteria for exercise. General physical activity refers to any body movement produced by skeletal muscles that results in energy expenditure. 'Exercise' refers to planned, structured activities of repeated body movements that seek to improve or maintain one or more component of physical fitness.[1] Exercise is distinct from general physical activity because exercise employs intensities, durations, and frequencies with the specific intent of changing specific components of fitness (such as aerobic capacity or muscle strength). Research aimed at evaluating exercise for children with CP can be divided into two categories: studies evaluating the effect of progressive resistive exercise and studies evaluating the effect of aerobic exercise.

LAND-BASED PROGRESSIVE RESISTANCE EXERCISE

Several studies have evaluated the effects of progressive resistive exercise (exercise that employs progressive levels of resistance with the intent of improving levels of muscle strength) for children with CP.[4,7,17,23,24,27–29,36] Existing studies report effects of progressive resistance exercise varying in length from 6 to 10 weeks and ranging in frequency from three to seven times a week. Studies of progressive resistance exercise have evaluated the effects of free weights,[4,7,17,24,29] isokinetic exercise,[9,27,28] and isometric exercise[9] held at a community gym,[17] combined home and clinic environments,[4,7,24] and in clinic, hospital, or laboratory settings.[27,28] A systematic review of this literature has been published.[37] Ten empirical studies and a previous review were critically reviewed and rated for methodological rigor. Most reviewed studies used a pretest–posttest study design without a concurrent control group. Of the remaining studies, one used a concurrent control group[27] and the other compared postintervention results with repeated baseline measurements.[17] Three other studies published after the review were identified, including a randomized controlled trial of 21 children aged 8 to 18 years performing repeated practice of step-up, toe raises, and squat activities against the resistance of a weighted backpack three times a week for 6 weeks.[38] A pretest–posttest study reported the effects of a 6-week progressive, resistive exercise program, targeting the trunk, hip, knee, and ankle flexors, performed three times a week by seven adolescents with CP.[36] A non-randomized ABA study involving children aged 4 to 8 years with a diagnosis of CP reported effects of a 4-week training program involving treadmill walking, balance exercises, ramp walking, stair walking, and closed-chain bodyweight resistance exercises.[23] The existing body of evidence suggests that progressive resistance exercise programs are effective in increasing the muscle strength of children with CP.[4,7–9,17,24,28,36–38] Although the effects of progressive resistive exercise on mobility, function, and participation have not been fully evaluated,[37] improved walking speed,[4] improved wheelchair endurance,[29] improved scores of perceived physical appearance,[17] and improved scores on the Gross Motor Function Measure[39] have been reported.[4,28] Reported effects of progressive resistance exercise on the Energy Expenditure Index (EEI),[40] a ratio of net walking and resting heart rates with walking velocity, are mixed. One study described improvement in EEI scores after training[36] and others reported no effect.[4,17,28]

LAND-BASED AEROBIC EXERCISE

Land-based aerobic exercise refers to exercise performed on land that targets aerobic parameters. Land-based aerobic exercise studies involving children with CP vary in program design and evaluation. They include training programs conducted in a laboratory setting[3,41,42] and in community and school-based settings.[17,26,35,43] Controlled laboratory-based cycling studies provide convincing evidence for the trainability of children with CP.[3,41,42] Authors of these studies report significant increases in maximal heart rate[41] and aerobic capacity.[3,42] Studies of land-based aerobic exercise training under less-controlled community and school-based environments describe the effects of dynamic aerobic exercise targeting large muscle groups and held two to four times a week.[17,26,35,43] In all four studies, heart rate was used to monitor exercise intensity. Reduced heart rate during submaximal exercise testing,[26] increased aerobic capacity,[35] and a decrease in oxygen consumption levels relative to workload[43] were reported after 6 weeks to 9 months of training. In contrast, EEI scores and submaximal heart rate relative to workload were unchanged in a group of 23 adolescents after a 10-week, three-times-a-week, community aerobic, strengthening, and flexibility program.[17] The differences in the outcomes reported in this study may be due either to the program parameters or to the less sensitive clinical outcome measures used.

A growing number of studies report the effects of land-based exercise for children with a diagnosis of CP. However, most studies have involved ambulatory children.[4,7,17,23,24,28,36,38,42] Little is known about the effects of land-based aerobic and progressive resistance exercise for non-ambulatory children. Attaining sufficient intensity, safety, and control of land-based aerobic and progressive resistance exercise for children with poor motor control, impaired balance, joint pathology, joint instability, and severe contractures may pose a challenge. Aquatic exercise may be a more suitable form of exercise for children with these types of impairment because their effects are minimized in water.

AQUATIC EXERCISE

Aquatic exercise is an attractive form of exercise for children with CP. The buoyancy of water decreases the influence of gravity and provides increased postural support.[30] These characteristics may allow children with CP to exercise in water with more freedom than on land. The resistive forces of buoyancy and viscous drag permit a variety of aerobic and strengthening activities that can be easily modified to accommodate the wide range of motor abilities of children with CP. An additional benefit of

aquatic exercise is the reduced levels of joint loading and impact,[30] providing a gentler environment for children with unstable joints[44] who experience persistent and abnormal loading.[37] Studies involving typically developing children and children with asthma report a significant improvement in aerobic capacity[45–47] for children engaging in aquatic exercise two or more times a week. Despite the theoretical benefits of aquatic exercise for children with CP, little research has been done on its effects. Although studies describing the effects of aquatic *therapy* (interventions in the water that are not intended to produce a fitness effect) exist,[48–57] few studies have evaluated the effects of aquatic *exercise*. An annotated bibliography of aquatic therapy[51] included only two studies involving children with CP.[53,54] More recently, a study involving an adult male with CP reports the effects of an aquatic aerobic and muscle resistance program.[30] Table I provides a summary of these studies.

These three aquatic exercise studies involving children with CP indicated positive effects, reporting improvements in flexibility,[54] respiratory function,[53] muscle strength, gait, and gross motor function.[30] However, the information from the existing literature is limited because the methodological rigor of the studies is weak. Peganoff[54] and Thorpe and Reilly[30] described effects for only a single participant and did not control for confounding variables such as coincidental events, or observer bias. In both studies only single pre-intervention measures were taken. In addition, all three studies failed to monitor the intensity of the aerobic exercise employed. None of the studies evaluated the potentially negative effect of aquatic exercise on levels of fatigue of children with CP. Additional research is required evaluating the effects of different durations, intensities, and frequencies of aquatic exercise on fitness levels of children with CP.

Aquatic exercise is a unique form of exercise that may be particularly useful for improving fitness levels of children with CP. However, several factors need to be considered when implementing aquatic exercise in children with CP. These include the following: (1) ensuring adequate intensity, duration, and frequency to promote a fitness effect; (2) determining when a group environment may be more beneficial than individual interventions; and (3) making sure that the pool environment is suitable and safe for intervention.

Promoting a fitness effect

According to the American College of Sports Medicine,[58] to target aerobic fitness, children should engage in aerobic exercise for 30 to 60 minutes, most or all days of the week. Bar-Or and Rowland[59] suggested an aerobic intensity of 60 to 70% of maximal oxygen uptake or 70 to 80% of maximal heart rate. In an aquatic environment, aerobic intensity can be monitored with waterproof telemetry heart-rate straps.[45–47,60,61] As an alternative, exercise intensity can also be monitored with scales of perceived exertion, such as the Children's OMNI Scale of Perceived Exertion.[62] A variety of aquatic exercises may be used to target aerobic fitness in the water for children with CP, including length swimming,[46,47,60,61] shallow-water tuck jumps, stride jumps, jumping jacks (star jumps), on-the-spot and propulsive running, and wall and sit kicking (i.e. holding onto the ledge and kicking the legs). Participation in aquatic exercise may be facilitated by support from the wall, a foam 'pool noodle' (a long, flexible buoyancy aid), a floating kick board, a floating barbell, a life or neck jacket, or another person (skilled in working in the water with individuals with physical disabilities).

To promote muscle strength, the American College of Sports Medicine recommends performing at least one set of 8 to 12 repetitions to volitional fatigue, twice a week.[58] Progressive resistance exercise performed in the water differs from progressive resistance exercise on land in the way in which resistance is applied. In the water, velocity and drag are used to produce resistance rather than gravity-resisted weight.[63] Poyhonen et al.[63] suggest that as the velocity doubles in the water, resistance provided by the drag force quadruples. Resistance is increased, therefore, as the child attempts to move his or her limb through a directed path of movement with increasing speed. Resistance can be further increased by the use of paddles, kick boards, and aquatic resistance boots.[30,63]

Group versus individualized exercise environments

Most aquatic therapy studies involving children with neurological conditions describe effects of individualized aquatic interventions.[30,48,54,] Aquatic exercise provided in a group environment can promote a motivating and socially stimulating therapy for children.[64] Within a group context, games, races, and cooperative activities can be used to enhance engagement of children with CP in exercise interventions. Although in some instances it may be beneficial to work individually with a child to ensure proper technique and intensity, group treatment permits peer modeling, competition, and potentially, a wider range of activity which may benefit the child's overall participation in the prescribed exercise.

Table I: Aquatic exercise studies involving children with cerebral palsy

Reference	*Group size and age*	*Study design*	*Exercise parameters*	*Exercise description*	*Results*
Peganoff[54]	*n*=1, 14y	Single subject	8wk; twice a week	Length swimming	Improved self-image; shoulder flexion and abduction range
Hutzler et al.[53]	*n*=46, 5–7y	Non-randomized controlled trial	6mo; swim twice a week, gym once a week	Land-based and aquatic movement exercises	Significant increase in vital capacity
Thorpe and Reilly[30]	*n*=1, 31y	Single subject	10wk; three times a week	Water walking, and lower extremity resistance exercises	Improved EEI and GMFM scores, gait velocity, self-perception, and muscle strength

EEI, Energy Expenditure Index; GMFM, Gross Motor Function Measure.

Environmental and safety considerations

The success of aquatic exercise interventions also depends on the suitability and safety of the aquatic environment. For children with varied motor abilities, ramps, chair lifts, stairs, and handrails may facilitate a child's ability to access the pool. Although there are unique benefits to deep-water and shallow-water interventions, for safety it is recommended that children be able to touch the bottom of the pool. Access to a large area of water that is shallow enough for all children in the group allows a maximum variety of jumping, running, walking, and strengthening activities. In addition, it is important to consider the child's ability to hold the ledge for support and reach the support quickly when in need. For children with balance impairments, the ability to readily access and hold the ledge will facilitate a child's ability and safety in participating. For children who are good swimmers and able to swim in the deep end, an underwater foot ledge at the pool's edge may benefit some children by reducing the requirements of the upper extremity to hold on during rest and edge time. It is also important that instructors, therapists, and parents assisting children in their aquatic exercise be familiar with ways of safely and securely supporting the child in an aquatic environment.

SUMMARY

As a form of therapy, exercise may benefit children with CP by improving muscle strength, cardiovascular function, and gross motor skill performance. Aquatic exercise is an appealing form of exercise for children with CP because of the unique properties of water that may reduce risks associated with joint loading, and may allow a child to engage more easily in intensified strength and/or aerobic activity than land-based exercise. Aquatic exercise may be of particular benefit to children with significant movement limitations for whom participation in land-based exercise may be limited. Unfortunately, there is a lack of evidence for assessing the potential merit and safe application of aquatic exercise for children with CP. Further evidence is needed regarding the effects of aquatic exercise on fitness and its place in the physical management programs of children with CP.

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