University of Alberta

Effects of aquatic exercise on the energy expenditure, levels of fatigue, and motor function of children with cerebral palsy

by

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Dedication

-To my supervisor and mentor Johanna Darrah
for your support, commitment, and exceeding abilities in instruction that inspired me to grow far beyond what I could have ever imagined.

-To my Mother, Father, and sister (Andrea)
for your understanding, patience, prayers, and encouragement.

-To my network of friends and family
for blessing me with your faith and unrelenting support.

Abstract

A community-based group aquatic aerobic exercise program for children with cerebral palsy was evaluated. Five children (8-12 years) completed 3, 1 hour aquatic aerobic training session per week for 12 weeks. Effects on the Energy Expenditure Index (EEI) and Pediatric Quality of Life Fatigue Scale (PedsQL-Fatigue Scale) were evaluated over a four-week baseline phase, throughout the 12-week intervention phase, and twice post- intervention. Pre and post measures of Canadian Occupational Performance Measure (COPM) scores for a self-identified gross motor goal were also taken. Significant changes were observed in COPM scores for all children in the program. EEI and Peds-QL Fatigue Scale scores were unchanged when compared to pre-intervention scores. A short term-intensive aerobic aquatic exercise program for children with cerebral palsy resulted in improved satisfaction and performance of gross motor skills without adverse effect on fatigue levels during daily activities.

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CHAPTER 1

Introduction

Introduction to the Thesis

Physical therapy approaches for children with a diagnosis of cerebral palsy are changing. Some therapists are now placing less emphasis on children with cerebral palsy achieving normal patterns of movement, and instead are more interested in the children attaining efficient and effective motor skills that promote success in identified functional tasks (Darrah, Law, & Pollock, 2001; Ketelaar, Vermeer, Hart, van Petegem-van Beek, & Helders, 2001). As a result, energy efficiency and measures of body functions, rather than patterns of movement, are considered important treatment goals. Instead of focusing solely on intervention relating to changes in body systems and functions, physical therapists are expanding service to address needs relating to activity performance and participation, as described in the International Classification of Functioning, Disability, and Health (ICF) (World Health Organization, 2001). In addition, therapists are considering community-based and group therapy as alternatives to traditional hands-on, clinic-based, individualized interventions.

The dynamic systems theory, a contemporary theory to explain motor development (Kamm, Thelen, & Jenson, 1990), has also contributed to changes in pediatric physical therapy practice. Because of its influence, some therapists are questioning the traditional neurological focus of intervention and considering the influence of other factors on motor behavior occurring within the child, the environment, and the task (Darrah et al., 2001; Keelaar, et al., 2001; Law et al., 1998). In exploring the influence of other parameters such as muscle strength, endurance, and flexibility, some therapists are now considering fitness training as a therapeutic intervention (Campbell, 1997; Damiano, Dodd, & Taylor, 2002; Darrah, Wessell, Nearingburg, & O'Connor, 1999; Eagleton, Iams, McDowell, Morrison, & Evans, 2004). Physical therapy practice is changing as therapists re-evaluate the type, mode, and location of service provided to children with cerebral palsy. One new service delivery option is fitness programs.

Statement of Problem

Physical fitness levels are reportedly reduced in children with cerebral palsy (Dresen, de Groot, Bradt Corstius, Krediet, & Meijer, 1982; Dresen, Vermuelen, Netelenbos, & Krot, 1982; Hoofwijk, Unnithan, & Bar-Or, 1995; van den Berg-Emons, Saris, de Barbanson, Westerterp, Huson, & van Baak, 1995). Reduced levels of cardiovascular endurance, strength, and flexibility may contribute to an increased risk of developing secondary impairments for children with cerebral palsy that may influence their function (Ayyangar, 2002; Dresen, Vermuelen et al., 1982; Durstine, Painter, Franklin, Morgan, Pitetti, & Roberts, 2000; Rimmer, 2001; van den Berg-Emons, Saris, deBarbanson, Westerterp, Huson, & vanBaak, 1995), and quality of life (Campbell, 1997; Durstine et al., 2000). Fitness interventions are appealing because they are accessible within the child's community and they address many aspects of physical functioning that are of interest to physical therapists. Aquatic exercise is one fitness option that may be suitable for children with cerebral palsy as it provides postural support (Harris, 1978) and reduces gravitational forces that may limit movement for children with cerebral palsy (Thorpe & Reilly, 2000). Scarce evaluation of its effects in altering physical fitness and function of children with cerebral palsy exists.

Aim of the Study

The aim of this study was to evaluate the effects of a 12-week, three-times-a-week, community-based aquatic exercise program for children with cerebral palsy. Changes in energy expenditure, levels of fatigue, and motor function were examined. Effects were evaluated using a simultaneous-replication, single-subject ABA design. Children's baseline performance on energy expenditure and fatigue were measured over the course of four weeks. Following the baseline phase, children engaged in three one-hour aquatic exercise sessions per week for 12 weeks. A probe measure was taken six to eight weeks following the conclusion of the intervention to evaluate the maintenance of observed effects.

Overview of the Thesis

The thesis follows a non-traditional format and consists of two distinct papers. The first, presented as Chapter 2, provides an overview of fitness literature involving children with cerebral palsy with a specific emphasis on aquatic exercise interventions. In Chapter 3, the study is described. Chapter 4 consists of a synopsis of the results, clinical implications, and plans for dissemination of the results.

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CHAPTER 2

Exercise Interventions for Children with Cerebral Palsy – is Aquatic Exercise a Viable Alternative?

Introduction

Exercise interventions refer to planned, structured activities involving repeated movement produced by skeletal muscles that result in energy expenditure with the specific objective of improving or maintaining levels of physical fitness (Caspersen, Powell, & Christenson, 1985). Exercise interventions targeting physical fitness levels of children with cerebral palsy are increasingly being considered for their potential to improve levels of muscle strength (Damiano, Dodd, & Taylor, 2002), aerobic capacity (Katsimanis, Evaggelinou, Christoulas, Kandrali, & Angelopoulou, 2002), and gross motor functional skills (Damiano & Abel, 1998). Forms of exercise and activity repetition have been included as components of therapy programs for children with cerebral palsy in the past (Heriza & Sweeney, 1995). However historically strenuous physical activity was discouraged because of concern about the effect of such effort on muscle spasticity and children's movement patterns (Bobath, 1971). Several factors have contributed to a recent shift in perspective regarding the potential therapeutic applicability of exertive exercise interventions for children with cerebral palsy. Studies evaluating the effects of exercise report no adverse affect of exercise on patterns of movement (Damiano, Kelly, & Vaughan, 1995; Holland & Steadward, 1990), flexibility (Healy, 1958; Holland & Steadward, 1990), or spasticity (Fowler, Ho, Nwigwe, & Dorey, 2001). The

World Health Organization's International Classification of Disability, Function, and Health (ICF) (World Health Organization, 2001) has influenced therapy by moving away from a "consequences of disease" classification to one that acknowledges multiple factors that contribute to a child's health. The ICF philosophy 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 (DST) 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 (Heriza & Sweeney, 1994; Kamm, Thelen, Jensen, 1990; Newell, 1986; Thelen, 1995; Thelen, 1989). Approaches based on DST principles emphasize the child's active and volitional role in therapy and target subsystems within the child (e.g. muscle strength, cardiovascular fitness) in addition to the central nervous system (Darrah, Law, & Pollock, 2001; Law et al., 1998). DST has led some 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 cerebral palsy (Darrah, Wessel, Nearingburg, & O'Connor, 1999). Exercise interventions for children with physical disabilities are also among key strategies identified in national and international health promotion initiatives (US Department of Health and Human Services, 2000; Canadian Public Health Association, 1999) and are considered instrumental in reducing the risks of factors such as fatigue (Dresen, Vermuelen, Netelenbos, & Krot, 1982; Jahnsen, Villien, Stranghelle, & Holm, 2003), decreased cognitive attention (Dresen et al., 1982), and decreased working efficiency (Fernandez, Pitetti, & Betzen, 1990) among individuals with cerebral palsy. Because of these factors, parameters such as muscle strength and aerobic capacity are receiving increased attention as an intervention option with children with cerebral palsy.

Research evaluating the effects of exercise interventions for children with cerebral palsy has focused primarily on the effects of on-land exercise intervention programs (Blundell, Shepherd, Dean, Adams, & Cahill, 2003; Damiano & Abel, 1998; Damiano, Kelly et al., 1995; Damiano, Vaughan, & Abel, 1995; Darrah et al., 1999; Dresen, de Groot, Mesa Menor, & Bouman, 1985; Lundberg, Ovensfors, & Saltin, 1967; McCubbin & Shasby, 1985; MacPhail & Kramer, 1985; O'Connell & Barnhart, 1995). Aquatic exercise may be a suitable alternative for children with cerebral palsy because of the unique properties of water that decrease joint loading and impact (Thorpe & Reilly, 2000) and provide postural support (Harris, 1978). Children with mobility impairments may perform exercise in the water more easily than on-land because the negative influences of poor balance, poor postural control, and excessive joint loading are reduced in the water environment. In this paper we review the research of exercise interventions for children with cerebral palsy, and then introduce aquatic exercise for its potential as an exercise option.

Exercise Interventions for Children with Cerebral Palsy

Exercise Interventions versus Physical Activity Interventions

One challenge of existing fitness studies involving children with cerebral palsy is the lack of distinction between general physical activity and exercise intervention programs. Although studies evaluating a wide variety of physical activity programs for children with cerebral palsy exist (Bar-Or, Inbar, & Spira, 1976; Blundell et al., 2003; Damiano & Abel, 1998; Damiano, Kelly, et al., 1995; Darrah et al., 1999; Dresen et al., 1985; Ekblom & Lundberg, 1968; Lundberg et al., 1967; Katsimanis et al., 2002; MacPhail & Kramer, 1995; Rintala, Lyytinen, & Dunn, 1990; van den Berg-Emons, van Baak, Speth, & Saris, 1998), they do not all satisfy the criteria for exercise. Physical activity interventions refer to any bodily movement produced by skeletal muscles that results in energy expenditure. *Exercise* interventions refer to planned, structured activities of repeated bodily movements that aim to improve or maintain one or more component of physical fitness (Caspersen et al., 1985). Exercise interventions are unique from recreation and general activity interventions because they employ intensities, duration, and frequencies with the specific intent of producing a fitness effect. Research involving exercise interventions for children with cerebral palsy can be divided into two categories, progressive resistive muscle training and aerobic exercise interventions.

Progressive Resistance Muscle Training

A number of studies have evaluated the effects of progressive resistive muscle strengthening programs for children with cerebral palsy (Blundell et al., 2003; Damiano & Abel, 1995; Damiano, Kelly et al., 1995; Damiano, Vaughan, et al., 1995; Darrah et al., 1999; Dodd, Taylor, & Graham, 2003; Eagleton, Iams, McDowell, Morrison, & Evans, 2004; MacPhail & Kramer, 1995; McCubbin & Shasby, 1985; O'Connell & Barnhart, 1995). Existing studies report effects of training programs varying in length from six to ten weeks, and ranging in frequency from three to seven times per week. Studies of resistance training have evaluated the effects of free weights (Damiano & Abel, 1998; Damiano, Kelly et al., 1995; Damiano, Vaughan et al., 1995; Darrah et al., 1999; O'Connell & Barnhart, 1995), isokinetic exercise programs (MacPhail & Kramer, 1995; Healy, 1958; McCubbin & Shasby, 1985), and isometric exercise interventions (Healy, 1958) held at a community gym (Darrah et al., 1999), combined home and clinic environments (Damiano & Abel, 1998; Damiano, Kelly et al., 1995; Damiano, Vaughan et al., 1995), and in clinic, hospital, or laboratory settings (MacPhail & Kramer, 1995; McCubbin & Shasby, 1985). A systematic review of this literature has been published (Dodd, Taylor, & Damiano, 2002). Ten empirical studies and a previous review were critically reviewed and rated for methodological rigor. The majority of reviewed studies used a pre-post test study design without a concurrent control group. Of the remaining studies, one used a concurrent control group (McCubbin & Shasby, 1985) and the other compared post-intervention results with repeated baseline measurements (Darrah et al., 1999). Three other studies published after the review were identified including a randomized controlled trial of 21 children ages 8 to 18 years performing repeated practice of step up, toe raises, and squat activities against the resistance of a weighted back pack three times per week for six weeks (Dodd et al., 2003). A pre-post study reported effects of a six week progressive resistive muscle training targeting the trunk, hip, knee, and ankle flexors performed three times per week for seven adolescents with cerebral palsy (Eagleton et al., 2004). A nonrandomized ABA study involving four to eight year olds with a diagnosis of cerebral palsy reported effects of a four-week training program involving treadmill walking, balance exercises, ramp walking, stair walking, and closed chain body-weight resistance exercises (Blundell et al., 2003). The existing body of evidence suggests muscle strengthening programs are effective in increasing the muscle strength of children with cerebral palsy (Darrah et al., 1999; Dodd et al., 2003; Dodd et al., 2002; Damiano & Abel, 1998; Damiano, Kelly et al., 1995; Damiano, Vaughan et al., 1995; Eagleton et al., 2004; Healy, 1958; Holland & Steadward, 1990; MacPhail & Kramer, 1995; O'Connell & Barnhart, 1995). Although the effects of strength training on mobility, function, and participation have not been fully evaluated (Dodd et al., 2002), improved walking speed (Damiano & Abel, 1998), improved wheelchair endurance (O'Connell & Barnhart, 1995), improved scores of perceived physical appearance (Darrah et al., 1999), and improved scores on the Gross Motor Function Measure (GMFM) (Russell, Rosenbaum, Cadman, Gowland, Hardy, & Jarvis, 1989) have been reported (Damiano & Abel, 1998; MacPhail & Kramer, 1995). Results of effects of progressive resistance muscle training on the Energy Expenditure Index (EEI) (Rose, Medeiros, & Parker, 1985), a ratio of net walking and resting heart rates with walking velocity, are mixed. One study described improvement in EEI scores following training (Eagleton et al., 2004) and others reported no effect (Damiano & Abel, 1998; Darrah et al., 1999; MacPhail & Kramer, 1995).

Aerobic Exercise

On-land aerobic exercise studies involving children with cerebral palsy vary with respect to program design and evaluation. They include training programs conducted in a laboratory setting (Berg, 1970; Katsimanis et al., 2002; Shinohara, Suzuki, Oba, Kawasumi, Kimizuka, & Mita, 2002) and community and school-based settings (Darrah et al., 1999; Dresen & Netelenbos, 1983; Lundberg et al., 1967; van den Berg-Emons et al., 1998). Controlled laboratory-based ergometry studies provide convincing evidence for the trainability of children with cerebral palsy (Berg, 1970; Katsimanis et al., 2002; Shinohara et al., 2002). Authors of these studies report significant increases in maximal heart rate (Berg, 1970) and aerobic capacity (Katsimanis et al., 2002; Shinohara et al., 2002). Studies of aerobic exercise training under less-controlled community and school-based environments describe the effects of dynamic aerobic exercise targeting large muscle groups held two to four times per week (Darrah et al., 1999; Dresen & Netelenbos, 1983; Lundberg et al., 1967; van den Berg-Emons et al., 1998). In all four studies, heart rate was used to monitor exercise intensity. Reduced heart rate during submaximal exercise testing (Lundberg et al., 1967), increased aerobic capacity (van den Berg-Emons et al., 1998), and a decrease in oxygen consumption levels relative to workload (Dresen & Netelenbos, 1983) are reported following six weeks to nine months of training. In contrast, EEI scores and submaximal heart rate relative to workload were unchanged in a group of 23 adolescents following a 10-week, three times per week community aerobic, strengthening, and flexibility program (Darrah et al., 1999). 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 fitness interventions for children with a diagnosis of cerebral palsy. The majority, however, have involved ambulatory children (Blundell et al., 2003; Damiano & Abel, 1998, Damiano, Kelly et al., 1995, Damiano,Vaughan et al., 1995; Darrah et al., 1999; Dodd et al., 2003; Eagleton et al., 2004; MacPhail & Kramer, 1985; Shinohara et al., 2002). Little is known about the effects of aerobic and resistance exercises for non-ambulatory children. Attaining sufficient intensity, safety, and control of on-land aerobic and 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 medium for fitness interventions for children with these types of impairments because their effects are minimized in the water environment.

Aquatic Exercise

Aquatic exercise is an attractive exercise alternative for children with cerebral palsy. Buoyancy of the water decreases the influence of gravity and provides increased postural support (Thorpe & Reilly, 2000). These characteristics may allow children with cerebral palsy to exercise more easily in water than on-land. The resistive forces of buoyancy, viscous drag, and the supportive nature of water also allow for a variety of aerobic and strengthening activities that can be easily modified to accommodate the wide range of motor abilities of children with cerebral palsy. An additional benefit of aquatic exercise is the reduced levels of joint loading and impact (Thorpe & Reilly, 2000) providing a gentler environment for children with unstable joints (Curtis & Gailey, 1996) that experience persistent and abnormal loading (Dodd et al., 2002). Studies involving typically developing children and children with asthma report significant improvement in aerobic capacity (Matsumoto et al., 1999; Obert, Courteix, Lecoq, & Guenon, 1996; Varray, Mercier, Terral, & Prefaut, 1991) for children engaging in aquatic exercise two or more times per week. Despite the theoretical benefits of aquatic exercise for children with cerebral palsy, little research is available on this intervention. Although studies describing the effects of water-based interventions exist (Attermeier, 1983; Bumin, Uyanik, Yilmaz, Kayihan, & Topcu, 2003; Dorval, Tetrault, & Caron, 1996; Dumas & Franscesconi, 2001; Figuers, 1999; Hutzler, Chacham, & Bergman, 1998; Peganoff, 1984; Sweeney, 1983; Thorpe & Reilly, 2000; Vogtle, Morris, & Denton, 1998, Yaggie & Armstrong, 2002), few studies have evaluated the effects of aquatic exercise on specific fitness parameters. An annotated bibliography of aquatic *therapy* (Dumas & Franscesconi, 2001) included only two studies involving children with cerebral palsy (Hutzler et al., 1998; Peganoff, 1984). More recently, a study involving an adult male with cerebral palsy reports the effects of an aquatic aerobic and muscle resistance program (Thorpe & Reilly, 2000). Table 2-1 provides a summary of these three studies.

Studies of aquatic exercise involving children with cerebral palsy provide some indication regarding its potential effects; however, the methodological rigor of these studies is weak. Peganoff (1984) and Thorpe & Reilly (2000) described effects for only a single participant and did not control for confounding variables such as maturity, co-incidental 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. Additional research is required to understand the effects of aquatic-based progressive resistive muscle strengthening for children and to better understand the effects of aerobic-based exercise interventions for children with cerebral palsy. Studies evaluating the effects of different exercise durations, intensities, and frequencies on fitness levels of children with cerebral palsy will also inform clinical practice.

Aquatic exercise is a unique fitness medium that may be particularly useful for improving fitness levels of children with cerebral palsy with significant mobility impairments. Several factors need to be considered when implementing an aquatic exercise intervention as therapy for children with cerebral palsy. These include: (a) ensuring adequate intensity, duration, and frequency to promote a fitness effect, (b) determining when a group environment may be more beneficial than individual interventions, (c) making sure the pool environment is suitable for intervention.

Promoting a fitness effect. According to the American College of Sports Medicine (ACSM) (2001), in order to target aerobic fitness, a child should engage in aerobic-aquatic exercise for 20 to 60 minutes, three to five days a week at an intensity of 65 to 90% of maximal heart rate (or 50-85% of VO2 max). In an aquatic environment, aerobic intensity may be monitored using waterproof telemetry heart rate straps (Matsumoto et al., 19991 ; Obert et al., 1996; Takken, van der Net, Kuis, & Helders, 2001; Takken, van der Net, & Helders, 2001; Varray et al., 1991). As an alternative, exercise intensity may also be monitored using scales of perceived exertion such as the Children's Effort Rating Table (CERT) (Lamb, 1995), or the Children's OMNI Scale of perceived exertion (Robertson et al., 2002). A variety of aquatic activities may be used to target aerobic fitness for children with cerebral palsy, including length swimming (Obert et al., 1996; Varray et al., 1991; Takken et al., 2003; Takken et al., 2001), shallow water tuck jumps, stride jumps, jumping jacks, on the spot running, propulsive running, water walking, wall kicking, and sit kicking. Participation in aquatic activity may be facilitated by support from the wall, a noodle, a floating kick board, a floating barbell, a life jacket, a neck jacket, or another person.

To promote muscle strength, the ACSM recommends performing at least one set of 8-12 repetitions to volitional fatigue, twice a week (ACSM, 2001). Aquatic-based progressive resistive exercise differs from on-land muscle strengthening in the way resistance is applied. In the water, velocity and drag are used to produce resistance rather than gravity-resisted weight (Poyhonen, Sipila, Keskinen, Hautala, Savolainen, & Malkia, 2002). Poyhonen et al. (2002) suggest that as the velocity doubles in the water, resistance provided by the drag force quadruples. Resistance is therefore increased 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, flutter boards, and aquatic resistance boots (Poyhonen et al., 2002; Thorpe & Reilly, 2000).

Group versus individualized intervention. The majority of aquatic *therapy* studies involving children with neurological conditions describe effects of individualized aquatic interventions (Attermeier, 1983; Peganoff, 1984; Thorpe & Reilly, 2000; Vogtle et al., 1998). Group aquatic activities can provide a motivating, engaging, and socially stimulating alternative for therapy for children (Bacon, Nicholson, Binder, & White, 1991). Within a group context, games, races, and cooperative activities can be used to enhance engagement of children with cerebral palsy in aerobic and strength interventions. Although in some instances it may be beneficial to work one on one with a child to ensure proper technique and intensity, group treatment allows for peer modeling, competition, and potentially a wider range of activity which may benefit the child's overall participation in the prescribed activity.

Environmental considerations. The success of the intervention also depends on the suitability of the aquatic environment. For children with varied motor abilities, ramps, chair lifts, stairs, and handrails may facilitate a child's ability to get in and out of the pool. Although there are unique benefits to deep versus shallow water interventions, for safety, it is recommended that all children in the group be able to touch the bottom of the pool. In many instances the shallow end of a pool is of variable depths. Having access to a large area of water that is shallow enough for all children in the group will enable maximum variety of jumping, running, walking, and strengthening activities. In addition, it is important to consider the ledge height. For children with balance impairments, the ability to readily access and hold the ledge may greatly facilitate a child's ability to participate. Handrails and flush ledges are often preferred to those that are raised as they are easy to access and lean on to. 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. Finally, a pool with an accessible entrance and adequate size of change rooms will also benefit the ability of the child and his/her family to engage in and enjoy their swim intervention experience.

Summary

As a therapeutic medium, exercise interventions may benefit children with cerebral palsy by improving levels of muscle strength, cardiovascular function, and gross motor skill performance. Aquatic exercise is an appealing fitness alternative for children with cerebral palsy because of the unique properties of water that may reduce risks associated with joint loading, and may allow a child to more easily engage in intensified strength and/or aerobic activity than on land. Aquatic exercise interventions may be of particular benefit for children with significant movement limitations for whom participation in on-land exercise may be limited. Unfortunately, there is a lack of evidence to understand the potential merit and safe application of aquatic-based exercise programming for children with cerebral palsy. Further evidence regarding the potential effects of aquatic fitness for children with cerebral palsy will better inform clinical practice about its potential as a therapeutic alternative.

Table 2-1. Aquatic Exercise Studies involving Children with Cerebral Palsy

	Group size and age	**Study Design**	**Exercise Parameters**	**Exercise Description**	**Results**
Peganoff, 1984	N = 1, 14 years old	Single subject design	8 wks, 2X/wk.	Length swimming	Improved self-image; shoulder flexion and abduction range
Hutzler et al., 1998	N= 46 5-7 years old	Non-randomized controlled trial	6 months 2, 30 min. swim/wk. 1, 30 min.gym/wk.	On-land and in-water movement exercises	Significant increase in vital capacity
Thorpe and Reilly, 2000	N=1 31 years old	Single-subject design	10 wks 3X/wk.	Water walking, and lower extremity resistance exercises	Improved Energy Expenditure Index, Gross Motor Function Measure scores, gait velocity, self-perception, and muscle strength

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CHAPTER 3

Effects of Aquatic Exercise on Energy Expenditure, Fatigue, and a Self-Identified Motor Goal for Children with Cerebral Palsy

Introduction

A shift in pediatric physical therapy practice has resulted in many therapists re-evaluating traditional treatment assumptions and considering alternative approaches to intervention (Darrah, Law, & Pollock, 2001; Ketelaar, Vermeer, Hart, van Petegem-van Beek, & Helders, 2001). Active on-land aerobic and muscle resistance exercise interventions are increasingly being used to improve levels of muscle strength (Blundell, Shepherd, Dean, Adams, & Cahill, 2003; Damiano, Kelly, & Vaughan, 1995; Damiano, Vaughan, & Abel, 1995; Darrah, Wessel, Nearingburg, & O'Connor, 1999; Dodd, Taylor, & Graham, 2003; Eagleton, Iams, McDowell, Morrison, & Evans, 2004; MacPhail & Kramer, 1995; McCubbin & Shasby, 1985; O'Connell & Barnhart, 1995), aerobic capacity (Katsimanis, Evaggelinou, Christoulas, Kandrali, & Angelopoulou, 2002; Shinohara, Suzuki, Oba, Kawasumi, Kimizuka, & Mita, 2002), bone mineral density (Kitsios, Tsaklis, Koronas, Varsamis, Abatzides, & Angelopoulou, 2000), and gross motor skills (Damiano & Abel, 1998; MacPhail & Kramer, 1985). Aquatic exercise may be a suitable alternative for children with cerebral palsy because of the unique properties of water that decrease joint loading and impact (Thorpe and Reilly, 2000) and provide postural support (Harris, 1978). Children with mobility impairments may move more freely in the water and may perform exercise in the water with more ease than on-land because the negative influences of poor balance, poor postural control, and excessive joint loading are reduced in the water environment. As a fitness intervention, aquatic exercise has been shown to improve levels of aerobic capacity for typically developing children (Obert , Courteix, Lecoq, Guenon, 1996) and children with asthma (Matsumoto et al.,1999; Varray, Mercier, Terral, & Prefaut, 1991). Aquatic exercise has also been shown to increase muscle strength (Poyhonen, Sipila, Keskinen, Hautala, Savolainen, & Malkia, 2002). Little research exists regarding aquatic exercise interventions for children with cerebral palsy. Although studies describing the effects of aquatic therapy interventions exist (Attermeier, 1983; Dorval, Tetreault, & Caron, 1996; Harris & Thompson, 1983; Martin, 1983), few studies describe the effects of aquatic *exercise* interventions for children with cerebral palsy. Exercise interventions differ from more general aquatic therapy interventions in that they aim to improve one or more component of physical fitness such as cardiovascular endurance or muscle strength. To do so they employ exercise intensities, duration, and frequencies to produce a fitness effect (Caspersen, Powell, & Christenson, 1985). Only three studies were identified using a water exercise medium that targeted the fitness levels of children with cerebral palsy (Hutzler, Chacham, Szeinberg, & Bergman, 1998; Peganoff, 1984; Thorpe & Reilly, 2000).

Peganoff (1984) described the effects of a twice-weekly swim stroke instruction program for a 14-year-old female with a diagnosis of spastic hemiplegia. Following eight weeks, improved range of motion, motor planning, balance, and bilateral coordination were observed. In another study, significant improvements in vital capacity were observed among a group of preschool children with mixed types of cerebral palsy following a six-month, trice-weekly swim and gym program (Hutzler et al., 1998). Finally, Thorpe and Reilly (2000) report effects of a single-subject design study. In this study, a 31-year-old male with cerebral palsy performed aquatic resistance and water-walking program three-times-a-week for 10 weeks. Improved Energy Expenditure Index (EEI) (Rose, Medeiros, & Parker, 1985) scores (representing a ratio of net walking and resting heart rate with velocity), gross motor function (dimensions D and E of the Gross Motor Function Measure (GMFM) (Russell, Rosenbaum, Cadman, Gowland, Hardy, & Jarvis, 1989)), gait velocity, Timed Up and Go test performance (Podsiadlo, & Richardsom, 1991)), and muscle strength were observed following the intervention. Improvements were maintained in gait velocity, GMFM dimensions D and E, and most lower extremity strength scores 11 weeks following the conclusion of the intervention phase.

Aquatic exercise is an appealing fitness alternative for children with cerebral palsy, but little is known about its effects (positive or negative). Although many authors promote the positive effects of on-land and aquatic-based exercise programs (Blanchard & Darrah, 1999; Durstine, Painter, Franklin, Morgan, Pitetti, & Roberts, 2000; Rimmer, 1999; Rimmer, 2001), little attention has been given to their potentially negative effects. Because children with cerebral palsy are less efficient in performing submaximal activity (Campbell & Ball, 1978; Dresen, de Groot, Mesa Menor, & Bouman, 1982; Dresen, Vermuelen, Netelenbos, & Krot, 1982; Rose, Gamble, Burgos, Medeiros, & Haskell, 1990;

Unnithan, Dowling, Frost, & Bar-Or, 1996), they may be more prone to fatigue than their typically developing peers (Dresen, Vermuelen et al., 1982). Participating in a fitness program may adversely affect a child's ability to complete daily tasks and activities because of increased levels of fatigue (Dresen, Vermuelen et al., 1982). Although no studies were found that evaluated the direct effects of exercise on the fatigue levels of children with cerebral palsy, Franks, Palisano, and Darbee (1991) reported decreased visuomotor performance following periods of exertive activity for a group of children with myelomeningocele. For a group of children with cerebral palsy, a 10-week on-land aerobic and activity program resulted in increased classroom attention (Dresen, & Netelenbos, 1983). The potentially adverse fatigue effect of exercise programs for children with cerebral palsy are unknown and needs further study.

As pediatric physical therapy practice continues to evolve, fitness interventions are increasingly being considered as a therapy option for children with cerebral palsy. Aquatic-based fitness interventions are appealing because of their unique properties that may serve as a suitable form of exercise intervention for children with cerebral palsy. Unfortunately, limited evidence exists to guide its clinical application. The purpose of this study was to evaluate the effects of a 12 week, three-time-a-week aquatic aerobic exercise program for five children with a diagnosis of cerebral palsy.

Methods

Design

A simultaneous-replication, single-subject ABA design was used to evaluate changes in energy expenditure, perceived fatigue, and perceived satisfaction and performance on a self-identified functional motor goal for children with cerebral palsy. Data were collected over a four-week baseline phase, during the 12-week intervention phase, immediately following the intervention phase, and six to eight weeks post-intervention.

Participant Selection

Five children participated in the study. Children were eligible for the study if they were 8 to 12 years of age, had a diagnosis of cerebral palsy and could walk independently (with or without aids) for at least five minutes, were able to move in the water safely for at least 25 meters, and were able to follow simple instructions. Their families had to commit to attending the program three times a week. Children were excluded if any of the following conditions were present: (a) an increase in regular therapy was anticipated during the study, (b) participation in an aerobic program occurring more than three times per week, (c) surgery or pharmaceutical intervention was scheduled within six months of the beginning of the study, and (d) cardiovascular pathology.

Following ethical approval, advertisements describing the study were placed in two local newsletters for families with children with special needs. In addition, therapists from a local private pediatric physical therapy clinic and the local pediatric hospital sent out letters of invitation to families or caretakers of eligible children from their caseloads. Twenty potential participants contacted the investigator (MK). Fifteen children did not meet the criteria for the following reasons: two were non-ambulatory, two children did not have a diagnosis of cerebral palsy, two children were not able to make the three times a week commitment, six children had a scheduling conflict with the prescribed swim times, one child had had surgery within the last six months, one family had transportation difficulties, and one child was not able to reliably follow verbal instructions.

Intervention

The aquatic-based aerobic exercise program was provided for one hour three-times-a-week for 12 weeks at a local swimming pool. A pediatric physical therapist (MK) with experience instructing young swimmers led all sessions and a lifeguard was on-duty for all swim times. Two assistants with experience working with children with special needs were available to ensure safety, and to provide individual assistance to children in the water if needed. Sessions involved 50 minutes of structured activities including warm-up and cool down periods. Children performed aquatic aerobic activities such as water walking, water running, jumping jacks, tuck jumps, sit kicking, length kicking, and lengths in circuit, race, choreographed aerobics, and game structures. Each session had at least 10 minutes of walking exercises such as tag, obstacle courses, and walking races (Appendix). The instructor encouraged all the children to exercise at an intensity level between 5 and 7 on the Children's OMNI scale of perceived exertion for children (Robertson et al., 2000). The OMNI scale is similar to the

Borg scale used to measure perceived exertion in adults (Borg, 1998). The Children's OMNI scale was developed specifically for children and uses a cartoon diagram of a child performing incremental stages of exercise intensity. The children were asked to look at the cartoon diagrams while MK pointed to the diagram and read aloud the descriptions. Children were then asked to point to the number that best described how his or her body felt during the activity. A score between 0 and 10 was obtained. During the aerobic component of each session, one or two children wore a POLAR heart rate monitor (Polar Electro Inc. Quebec, Canada) to monitor heart rate. This monitoring was done for all children at least six times during the study.

The program emphasized fun and group participation while trying to achieve sufficient exercise intensity to reflect an OMNI score of between 5 to 7. If a child was unable to attend a session, alternative swim times were scheduled if possible.

Outcome Measures

Three outcome measures were used to evaluate the effects of aquatic intervention. The EEI (Rose et al., 1985) was used as an indicator of energy expenditure, the Pediatric Quality of Life Multidimensional Fatigue Scale (PedsQL-Fatigue Scale) (Varni, Burwinkle, Katz, Meeske, & Dickinson, 2002) was used to measure the children's perceived levels of fatigue, the Canadian Occupational Performance Measure (COPM) (Law, Baptiste, Carswell, McColl, Palatajko, & Pollock, 1998) was used to measure satisfaction and performance of a self-identified motor goal.

EEI. The EEI has been used as an indicator of energy expenditure of typically developing children (Butler et al., 1984; Rose, Gamble, Lee, Lee, & Haskell, 1991) as well as with children with cerebral palsy (Damiano & Abel, 1998; Darrah et al., 1999; Kramer & MacPhail, 1994; MacPhail & Kramer, 1995; Mossberg, Linton, & Friske, 1990; Rose et al., 1990; Rose et al., 1985). It represents a ratio of resting and walking heart rate to walking velocity and results in units of beats per meter.

$$\frac{\text{Heart rate walking} - \text{Heart rate resting (beats per minute)}}{\text{Walking speed (meters per minute)}}$$

Concurrent validity correlation coefficients of .61 and 0.66 have been reported between the EEI and values of aerobic capacity (Bowen, Lennon, Castango, Miller, & Richards, 1998; Norman, Bossman, Gardner, & Moen, 2004). Test re-test reliability studies of the EEI over two testing sessions with children with cerebral palsy have reported correlation coefficients of 0.81 (Kramer & MacPhail, 1994). and 0.94 (Wiart & Darrah, 1999). However, reports of its validity and reliability are mixed; some authors support it as a useful indicator of energy expenditure (Butler et al., 1984; Mossberg et al., Norman et al., 2004; Rose et al., 1985; Rose, Gamble, Medieros, Burgos, & Haskell, 1989), while others have questioned its reliability (Boyd et al., 1999; Bowen et al., 1998) and validity (Hood, Granat, Maxwell, & Hasler, 2002; Keefer, Tseh, Caputo, Apperson, McGreal., & Morgon, 2004). The EEI was selected as an outcome measure for this study because it is an easy to administer measure of activity tolerance, and it has been used with children with cerebral palsy previously (Damiano & Abel, 1998; Darrah et al., 1999; Kramer & MacPhail, 1994; MacPhail & Kramer, 1995; Mossberg, Linton, & Friske, 1990; Rose et al., 1990; Rose et al., 1985).

The EEI was measured twice-a-week during the four week baseline phase. No data were collected during weeks one and two of the intervention phase because significant changes in heart rate and walking velocity were not anticipated during this short period of intervention. EEI data collection resumed on the third week of intervention and continued weekly until the conclusion of the 12-week intervention phase. EEI data were collected before the children exercised. The children were also assessed immediately following the last week of intervention, and again six to eight weeks post-intervention.

EEI testing procedures replicated procedures described by Darrah et al. (1999) and Rose et al. (1985). Two observers (a pediatric physical therapist and a registered nurse) were trained and achieved inter-rater reliability of 0.97. Testing occurred in a quiet hallway at the pool. Each child rested comfortably in supine for seven minutes, and the average heart rate during the last two minutes was recorded. After the rest period, the child walked continuously for five minutes at a self-selected, comfortable walking speed. An average heart rate reading of the last 30 seconds of the walk time was taken. On verbal cue, the child stopped and the child's distance was measured according to one-meter markings on the floor. If the child ended between two meter marks, a rolling tape measure was used to calculate the distance the child covered past the last marker. Heart rate was measured using a Polar Electro heart rate monitor. Following the test, heart rate information was downloaded and saved using Polar Precision Four software (Polar Electro Inc, Quebec Canada).

PedsQL-Fatigue Scale. The PedsQL-Fatigue Scale was developed by Dr. James W. Varni. The tool was developed in conjunction with two other tools evaluating different aspects of quality of life in children (Varni, Seid, & Kurtin, 2001; Varni, Seid, & Rode, 1999). Children were asked to respond to a series of eighteen questions pertaining to three areas: (a) general fatigue, (b) sleep and rest fatigue, and (c) cognitive fatigue. Children responded to questions about fatigue using a five point Likert scale. For example, under the general fatigue section children were asked: "In the past seven days, how much of a problem has this been for you...I feel tired never, almost never, sometimes, almost always, always" (Varni et al., 2002). Internal consistency scores using Cronbach's alpha range for the fatigue scale range from 0.74 to 0.88 for the child version. Statistically significant differences have been found between scores of 52 healthy children and 220 children with cancer (Varni et al., 2002). At each testing session, the primary investigator obtained verbal responses from children on the PedsQL-Fatigue Scale questionnaire. As recommended by the authors, raw scores were transformed into scale scores (0-100) (Varni, Burwinkle, Szer, 2004). Low Peds-QL Fatigue Scale scores represent high levels of fatigue.

PedsQL-Fatigue Scale scores were collected twice-a-week during the baseline phase. During the intervention PedsQL-Fatigue Scale scores were taken once-a-week starting on the third week of the intervention until its conclusion.

PedsQL-Fatigue Scale scores were also measured immediately following the last week of the intervention and six to eight weeks post-intervention.

COPM. The COPM was chosen to measure a functional goal identified individually by each of the participants. We wanted to include a measure at the level of activity as well as the two other measures at the level of body function and structure. The COPM has been used by clients and families with cerebral palsy to self-identify relevant and pertinent goals in their every day life (Law, Russell, Pollock, Rosenbaum, Walter, & King, 1999; Law et al., 1998; Pollock & Stewart, 1998). Test-retest reliability coefficients for its use with children and their families are reported to be 0.75 for satisfaction and 0.79 for performance (Law, Baptiste et al., 1998). It is considered responsive to detect change as a result of intervention (Law, Palatajko, Pollock, McColl, Carswell, & Baptiste, 1994).

Each child was asked to identify a functional activity that he or she either wanted to do better, or could not do and wanted to do. Emphasis was placed on activities specifically relating to motor skills (e.g., ride a bicycle faster, kick a ball farther). COPM scorecards were presented to each child. On each card the word performance or satisfaction was listed at the top with evenly spaced numbers ranging from 0 to 10 at the bottom. Children were asked how well/able they performed the identified activity and how happy/satisfied they were with their performance of the activity. COPM interviews occurred at the initial assessment, during the final week of the intervention, and six to eight weeks post-intervention.

Data Analyses

Data analyses evaluated changes within each child. Each child's scores for the EEI and the PedsQL-Fatigue Scale were plotted on a graph. Graphs included individual data points and a trend line for each phase (Figures 3-1 to 3-10). If scores were stable in baseline, the plotted line in baseline phase would have no slope. A slope of the baseline data line is problematic, especially if the slope of the intervention line is in the same direction, because even if the scores improve during the intervention phase, this 'trend' was already apparent during the baseline phase. In this instance, it cannot be assumed that the intervention had an effect on the scores (Portney & Watkins, 2000). Bandwidth lines representing plus and minus two standard deviations for baseline data were extrapolated into the intervention and follow-up phases. By convention, if at least two consecutive data points in the intervention phase fall outside the two standard deviation band, change is considered to reflect more than chance (Portney & Watkins, 2000). However, if the data path returns within the two standard deviation bandwidth even after two consecutive data points outside the bandwidth, and remain within the bandwidth for the remainder of the data collection period, it is unlikely that a true change has occurred.

Changes in performance and satisfaction on the COPM are described in terms of changes in raw scores. As recommended by the authors, a change in raw score of two or more is considered to represent a clinically significant change in function (Law, Baptiste et al., 1998). This method has been used by other authors to describe change in previous single subject design studies (Candler, 2003; Lammi & Law, 2003).

Results

Participant Descriptions

Child 1 was 9 years old with a diagnosis of spastic diplegia, level 1 on the Gross Motor Functional Classification System (GMFCS) (Palisano, Rosenbaum, Russell, Walter, Wood, & Galuppi, 1997). She had a busy extra curricular schedule and spent time being active with her siblings and peers. She had participated in recreational gymnastics and soccer and was working on riding her bicycle independently at the beginning of the baseline phase. Child 1 participated in 28 of 30 intervention sessions. She had an average exercise heart rate of 117 beats per minute during the exercise sessions.

Child 2 was 10 years old and has a diagnosis of spastic diplegia, GMFCS level 2. She described time spent playing sports and being active with her parents and sibling. She attended 33 of 36 intervention sessions. Child 2 was unable to participate in the six-week post-intervention follow-up testing because she had orthopedic surgery immediately following the intervention. Her average exercise heart rate was 126 beats per minute.

Child 3 was 10 years old with very mild left-sided hemiplegia, GMFCS level 1. He was very active and described playing running games and physical activities almost daily after school. He attended 35 of 36 intervention sessions. His average exercise heart rate during was 155 beats per minute.

Child 4 was 10 years old with a diagnosis of spastic quadriplegia, GMFCS level 3. He used a wheelchair as his primary form of mobility. He also used a Kaye walker to walk indoors. He attended 33 of 36 sessions. On average his exercise heart was 150 beats per minute.

Child 5 was 11 years old with a mild form of right-sided spastic hemiplegia, GMFCS level 1. She was involved in weekly recreational baseball during the study. She attended 24 of 30 interventions sessions; she was admitted into the study 2 weeks after the other children. Her average exercise heart rate was 126 beats per minute.

EEI

The EEI scores for each child were extremely variable, as seen in Figures 3-1 to 3-5. The EEI scores observed in our study are consistent with the range of EEI scores described in previous studies for children with similar forms of cerebral palsy (Ijzerman & Nene, 2002; Keefer et al., 2004; Mossberg et al., 1990; Rose, Haskell, Gamble, Hamilton, Brown, & Rinsky, 1994; Rose et al., 1985). Scores for Child 1 and Child 2 fell within ranges previously reported for children with spastic diplegia (0.36 to 1.89 beats per meter (bpm) (Mossberg et al., 1990), 0.83 to 1.25 bpm (Rose et al., 1994)). Scores for Child 3 and Child 5 were consistent with scores previously reported for children with hemiplegia (0.21-0.65 bpm (Ijzerman et al. 2002), 0.5-0.71 bpm by Keefer et al. 2004). And scores for Child 4 fell within ranges previously reported for children with spastic quadriplegia (3 to 12 bpm (Rose et al., 1985)).

The majority of EEI scores for Child 2 and Child 3 fell within their two standard deviation bandwidths. This indicated that any change observed during the intervention phase did not exceed that which would be expected as a result of natural variability observed in baseline. Data from Child 1 indicated an apparent deterioration in EEI scores during weeks 11 and 12 as these two consecutive points fall above the two standard deviation bandwidth. Her scores, however, quickly returned within the two standard deviation bandwidth and stayed there for the remaining four intervention data collection times, suggesting no systematic pattern of change. For Child 4, 11 of the 13 data points collected in the intervention and follow up phase fell below the two standard deviation bandwidth which could be interpreted as an improvement of EEI scores. However, because the data was already trending downwards in the baseline phase, it cannot be assumed that the improved EEI scores reflect change due to the intervention. Similarly, changes in EEI scores observed for Child 5 cannot be attributed to the aquatic intervention because two consecutive data points fell below the two standard deviation bandwidth lines prior to the intervention indicating that the change occurred before Child 5 started the intervention.

PedsQL-Fatigue Scale

Graphs of the PedsQL-Fatigue Scale scores were characterized by large variability (see Figures 3-6 to 3-10). For all children the majority of points fell within a two standard deviation of the baseline data indicating that any apparent change in the level or trend of the data did not exceed the variability of the child's natural performance prior to intervention.

COPM

Table 3-1 outlines COPM raw scores for all five children as collected prior to, immediately following, and six to eight weeks following the intervention. The scores of Child 1, Child 2, and Child 3 reflect their perceived satisfaction and performance of running fast. Child 4's scores refer to his ability in climbing the stairs and Child 5 described her performance and satisfaction regarding her ability to walk backwards. COPM scores for all five children changed by two or more from baseline to intervention. Changes appear to be maintained following a six to eight follow-up period.

In summary, following a 12-week aquatic intervention program, no conclusive changes were observed in EEI scores, and no changes were observed in PedsQL-Fatigue Scale following intervention. Changes in scores of perceived performance and satisfaction demonstrate are considerable from baseline to intervention and appear to be maintained following a six to eight week break.

Discussion

The purpose of this study was to evaluate the effects of an aquatic aerobic exercise program on the EEI, PedsQL-Fatigue Scale, and COPM scores of a self-identified gross motor skill for five children with cerebral palsy. The scores of both the EEI and the PedsQL-Fatigue Scale were characterized by large intra-individual variability in all phases of the study. This variability may be due to measurement error, or it may represent true intra-individual variability of scores in this population. Both of these possibilities are discussed. The EEI scores did not change dramatically in the intervention phase. In addition to the large variance of scores, lack of EEI changes may have been influenced by the intensity of training, the specificity of training, or the use of clinical measures. The clinical significance of no change in the PedsQL-Fatigue Scale scores is presented. Finally, the significance of the improved scores on the COPM for all the children regarding their identified goals is discussed.

Variability of EEI and PedsQL-Fatigue Scale Scores

The variability of scores on both the EEI and PedsQL-Fatigue Scale measures may represent poor reliability of the measure, true variability of the child's performance, or a combination of both. Some authors question the reliability of the EEI (Boyd et al., 1999; Bowen et al., 1998; Ijzerman and Nene, 2003). Discrepancies of scores between testing sessions, however, may represent more than measurement error. Several factors besides measurement error may explain the variability of EEI and Peds-QL scores including test adaptation (Keefer et al., 2004; Maltais et al., 2003), between test alterations in walking pattern (Maltais et al., 2003), muscle tone fluctuations, anxiety (Maltais et al., 2003), an unattained or unsustained steady state during walking (Boyd et al., Keefer et al., 2004; Maltais et al. 2003), influence of fuel and diet on resting metabolic parameters (Maltais et al., 2003), emotions, and environmental factors such as temperature (Keefer et al., 2004). Any one of these factors could explain the variability of our results. The EEI scores in this study may have been influenced by the children's level of fatigue and excitement or by the children's ability to rest during the seven minute rest period. Changes as a result of these factors may have affected the child's level of spasticity, gait velocity, and heart rate resulting in changes in EEI scores. In the same way, it is possible that PedsQL-Fatigue Scale scores were influenced by how much sleep children had had the night before testing and how active the children were prior to testing. Unfortunately no research was found regarding the reliability of PedsQL-Fatigue Scale for children with cerebral palsy. For researchers and clinicians currently using or considering these measures to evaluate changes in performance of children with cerebral palsy, a greater understanding of the source of variability is necessary.

Although the effects of measurement and true variability cannot be teased apart in this study, the large changes in scores within an individual over time are clinically relevant. Clinically and in research studies, often only one measure is collected before and after an intervention is initiated (pre-post testing). Single measures may not capture the true intra-individual variability of scores both before and during an intervention stages. Without repeated measures, changes observed following an intervention may be misinterpreted as true change when they may only reflect natural variability in the child's performance. The large variability of both EEI and PedsQL-Fatigue Scale scores observed in both the baseline and interventions phases of this study were striking. We feel therapists should be aware of the large variability that may occur when using clinically accessible measures such as the EEI and PedsQL-Fatigue Scale. Even large changes in scores may not reflect a true change in a child's performance because of the natural between-test fluctuation in scores that may occur. Multiple and repeated measures of clinical measures such as the EEI and Peds-QL Fatigue

Scale scores would allow therapists to more clearly distinguish true change from natural variability. To improve the interpretation of intervention results, we recommend multiple measures before and during the intervention.

Measures – Physiological versus Clinical

Clinically appropriate outcome measures such as the EEI are extremely popular and are prevalent in rehabilitation (Ijzerman and Nene 2002). These tools are used for both clinical and research evaluations of clients' performances. We chose the EEI because of its applicability and relevance for clinicians, however, the EEI does not appear to be as sensitive to small changes in children's aerobic performance as more technical laboratory measures (Boyd et al., 1999, Bowen et al., 1998, Ijzerman and Nene, 2002, Keefer et al., 2004). Fitness studies that have used laboratory based physiological measures demonstrate clear changes in aerobic capacity (Katsimanis et al., 2002; Shinohara et al., 2002; van den Berg-Emons et al., 1998). Results of studies using less technical clinical measures such as the EEI and submaximal heart rate tests, by comparison, failed to detect any change following aerobic interventions (Bar-Or, Inbar, Spira, 1976; Darrah et al., 1998; Dresen & Netelenbos, 1985). Clinical and research communities would benefit from intervention studies that report effects using both clinical and laboratory based measures. If we had used a more sensitive laboratory measures of energy expenditure such as oxygen cost (Bowen et al., 1998) we may have been able to detect smaller changes in performance.

EEI

No changes were observed in EEI scores following the 12 week intervention. This lack of change may be also explained by the intervention or the trainability of children with cerebral palsy.

Program Parameters

Intervention intensity. According to the American Academy of Pediatrics (AAP) (Dyment, 1991) in order to observe a change in aerobic parameters with typically developing children they must achieve a heart rate of 150 beats per minute during exercise. Only two of the five children in our study (Child 3 and Child 4) had an average exercise heart rate exceeding 150 beats per minute. Although it is recognized that the water environment may cause exercise heart rates to be lower (in-water heart rate is reported to be 13 beats per minute lower than on land (Dicarlo, Sparling, Millar-Stafford, & Rupp (1991)), exercise heart rates for Child 1, Child 2, and Child 5 were dramatically lower than the threshold recommended by the AAP (Dyment, 1991). All sessions in the study were constructed to maximize the participation and activation of children in the group, however, the range of abilities of children may have affected the achieved intensity of exercise of group members. In our study the child with the most significant motor impairment (Child 4) demonstrated the largest improvement in EEI scores. Particularly for the active and mildly involved children, grouping children with similar abilities may have been more effective in promoting exercise of an adequate intensity.

Specificity of training. Unchanged EEI scores may also be a result of specificity of training. Because the intervention occurred in the water, changes in aerobic function may have been specific to the water environment without carrying over to on-land performance. Although an in-water measure was initially considered as a part of the study, it was removed because the relevance of changed efficiency in the water was not deemed as functionally significant as changes on land. For future evaluation, effects of aquatic exercise intervention using in-water measures of aerobic function would provide clarity to the nature and the extent of the effects of aquatic exercise.

Trainability of children in the study. Rowland and Boyajian (1995) describe the effects of a 12-week aerobic exercise program and report improved walking economy of typically developing children using oxygen consumption during submaximal treadmill walking as an outcome measure. They suggest, however, that the degree of aerobic trainability may be limited in active children. The effect of previous activity levels on the children in this study may have influenced the observed results. In our study, four children (Child 1, 2, 3 and 5) had physically active lifestyles and only minimal to no changes in EEI were observed in these children following intervention. Child 4 was less physically active than the other children in the program and demonstrated a much larger change in EEI scores. It may be that Child 4 was less physically fit than the other children and therefore may have been more responsive to the program's effects.

A lack of change in EEI scores between baseline and intervention may have also resulted from parameters specific to the aquatic exercise intervention employed. Intervention intensity may have been inadequate, training effects may have been specific to an aquatic medium and not picked up by our on-land evaluations, and previous activity levels of children in the study may have left children with little room to improve their levels of aerobic fitness. Further research to evaluate the effects of aquatic exercise programs of different intensities, using in-water measures with children of various levels of previous activity levels would provide clarity regarding the utility of aquatic exercise as a therapy option for children with cerebral palsy.

PedsQL-Fatigue Scale

The effects of aerobic intervention on the fatigue levels of children with cerebral palsy has not been well evaluated. The unchanged PedsQL-Fatigue Scale scores in this study suggest that a three-times-a-week, intensive aerobic exercise program did not result in increased levels of fatigue for the children. Anecdotally, one of the parents had expected her child to demonstrate significant signs of tiredness and exhaustion, and she was pleased that her child remained energetic during and following the program. Another parent reported her child as having 'more energy' following the intervention. A third parent remarked on her child's ability to sleep better at night throughout the program. Future research evaluating the effects of exercise intervention of fatigue levels of children with cerebral palsy would contribute to a better understanding of the global effects of exercise programming for children with cerebral palsy.

COPM

Significant improvements in COPM scores of perceived satisfaction and performance of a self-identified goal were observed following the intervention. These results are consistent with subjective observations reported by parents involved in the study. Parents attributed the change in COPM scores to a combination of improved motor abilities and increased levels of overall confidence in their children. One parent shared that his child felt 'stronger'. Additional benefits described by parents following the study included reports of attaining independent swimming, self-toileting, and independent bicycling. These results are consistent with those described by Dorval et al. (1996) who describe significant improvements in scores on the pediatric version of the Functional Independence Measure (WeeFIM) (Granger, Hamilton, & Kayton, 1989)) in two groups involved in an aquatic therapy program. Changes in functional performance following an aquatic fitness program have also been reported previously for an adult male with cerebral palsy (Thorpe & Reilly, 2000). Improved levels of self-perception scores (Thorpe & Reilly, 2000) and self-perception of physical appearance (Darrah et al., 1998) are also described following aquatic exercise and fitness interventions. Research evaluating the relationship between observed changes in gross motor skill performance, changes in perceived performance and satisfaction of gross motor skill, and levels of self-efficacy would benefit clinical practice in better understanding the effects of fitness interventions on the gross motor functional of children with cerebral palsy.

Based on subjective feedback following the study, parents described their children as having had fun in the program, enjoying swimming, and meeting children with similar abilities and challenges. Commitment of families and children to the program is evident by the impressive attendance of the families and lack of attrition. Although the parents described the frequency of three times a week as being sometimes challenging, one parent felt that the benefits of regular exercise and stretching far outweighed the challenges of regular attendance. Another parent stated: "If this was ever offered as a therapy option. I would love to do it." This study provides evidence to the feasibility of maintaining participation of children with cerebral palsy in a community-based fitness program offered three times a week for 12 weeks.

Limitations

In single subject design research it is recommended that the baseline phase continue until stability of scores is observed (Bailey & Burch, 2002). In this study, a four week baseline was chosen. We tried to balance the need for an adequate number of data points and the time families were able to commit to the study. Because of the significant variability observed in our study it is possible that even with an extended baseline, stability may not have been achieved. However, by convention in single subject research, baseline is continued until stability is achieved. If stability were attainable with an extended baseline the results may have been more easily identified.

The EEI was selected as an indicator of energy expenditure because it is clinical applicable, easy to use, and affordable. The limitations of its ability to detect change for this population are recognized and have already been discussed. More sensitive and stable measures of energy expenditure such as oxygen cost (Bowen et al., 1998) may have detected more subtle changes than the EEI used in this study.

An additional limitation of our study is the limited generalizability of the results. It is recognized that results of this study are limited to the children in the study.

Conclusion

Results of this study suggest that a 12-week three-times-a-week aquatic exercise program can result in improved levels of perceived satisfaction and performance of gross motor skill performance in children with cerebral palsy without causing increased levels of fatigue. The large variability of both the EEI and PedsQL-Fatigue Scale suggest that repeated baseline, intervention, and follow-up should be considered for both clinical and research evaluations of intervention strategies with children with cerebral palsy. A relatively intensive aquatic exercise program for children with cerebral palsy was acceptable for families and enjoyable for the children involved.

Table 3-1. COPM Performance and Satisfaction Scores

Child	**Goal**	**COPM Score**			
			Baseline	Post-intervention	6 to 8 weeks post-intervention
1	Run Faster	Satisfaction	1	9	10
		Performance	1	9	9
2	Run Faster	Satisfaction	8	10	10
		Performance	5	10	10
3	Run Faster	Satisfaction	2	8	6
		Performance	4	6	6
4	Climb stairs	Satisfaction	1	4	10
		Performance	2	5	10
5	Walk backwards	Satisfaction	4	10	10
		Performance	6	10	10

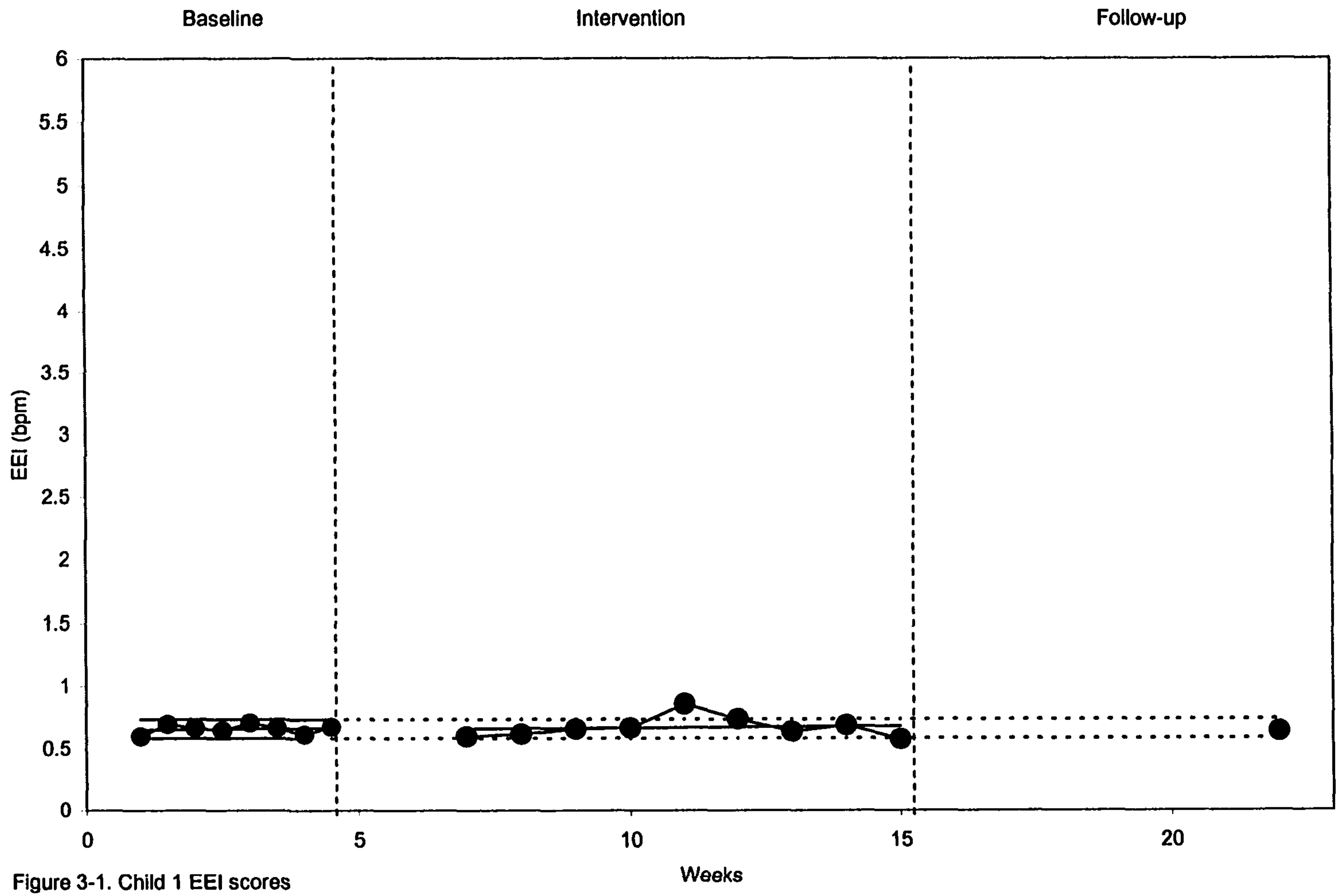

Figure 3-1. Child 1 EEI scores

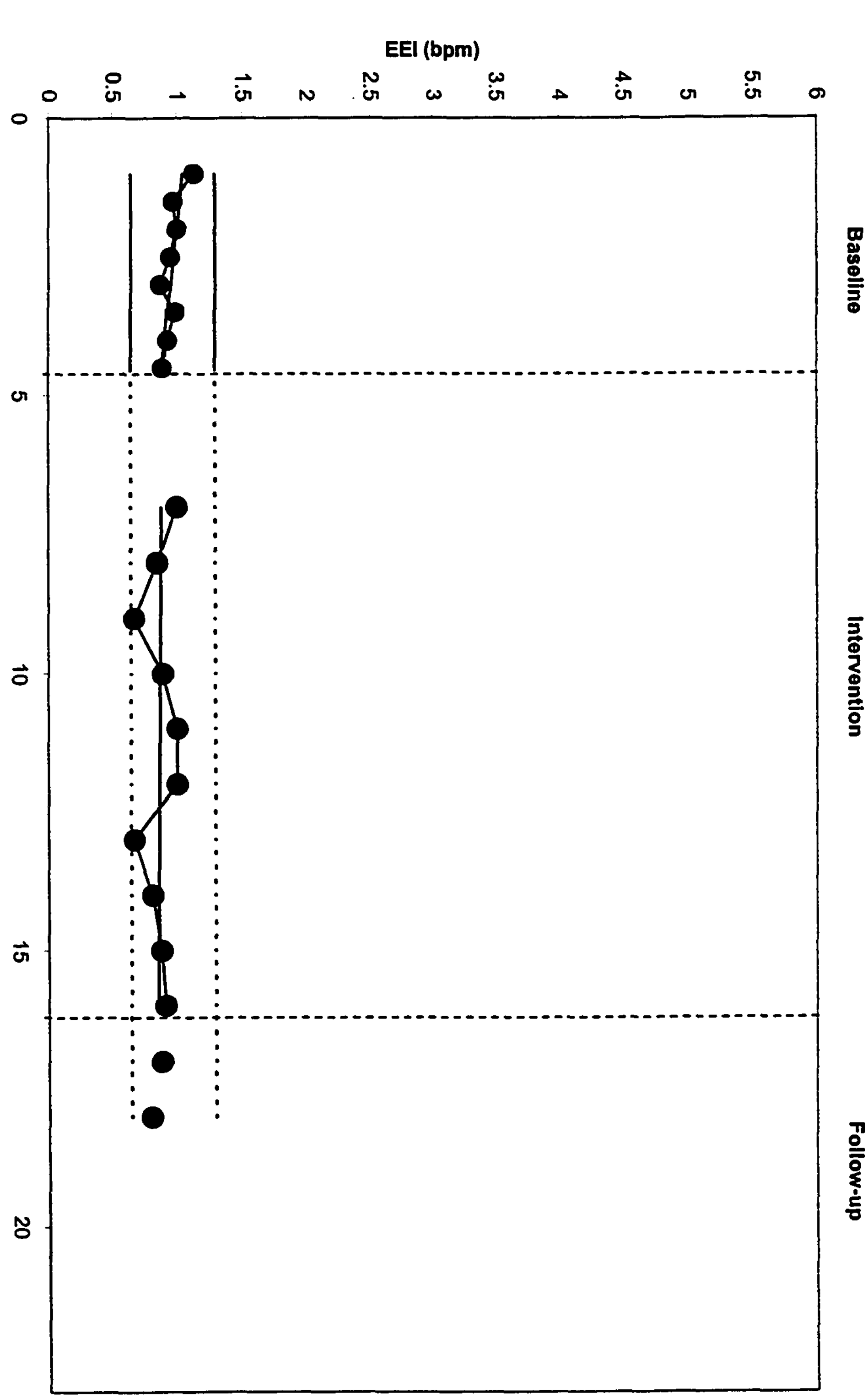

Figure 3-2. Child 2 EEI scores

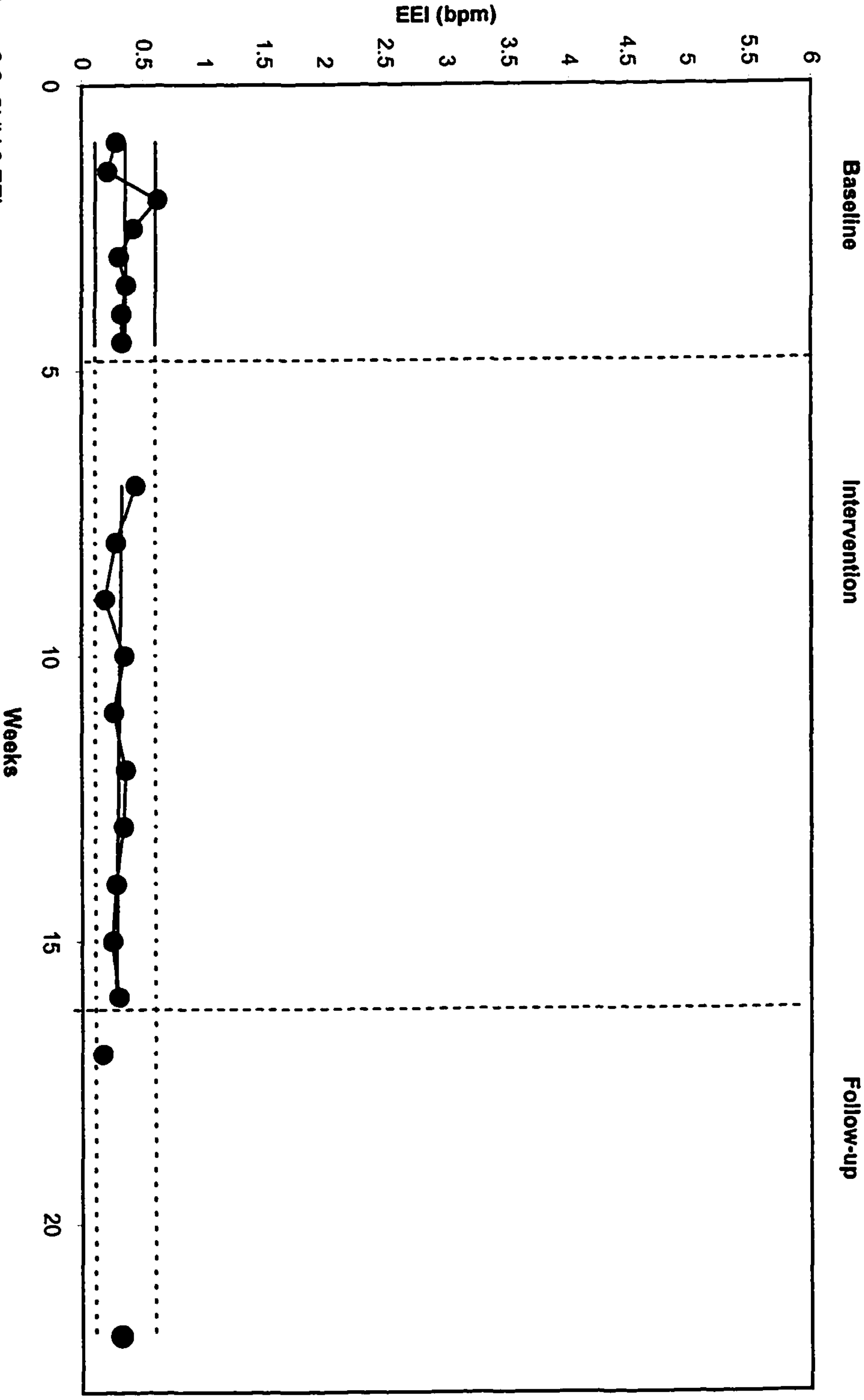

Figure 3-3. Child 3 EEI scores

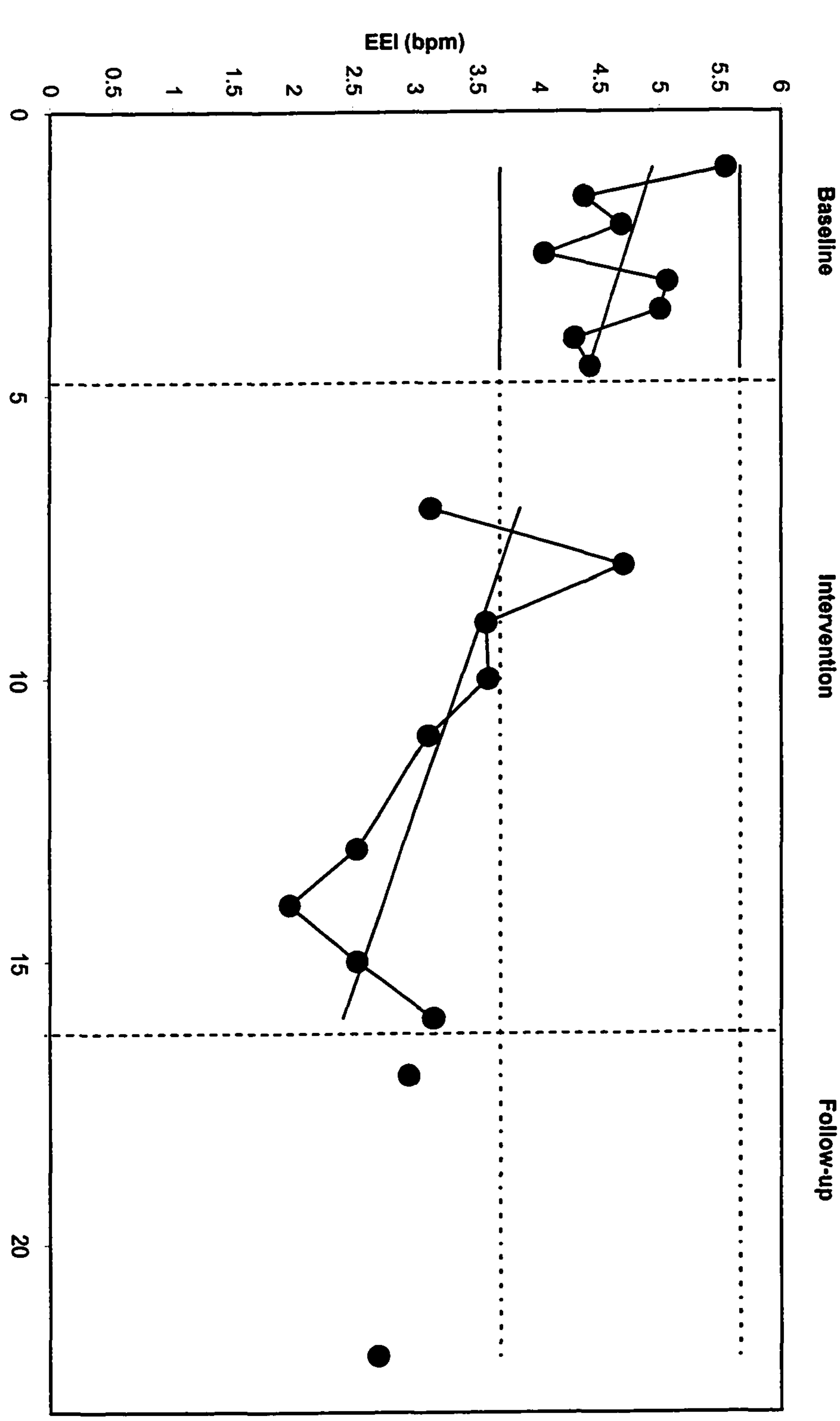

Figure 3-4. Child 4 EEI scores

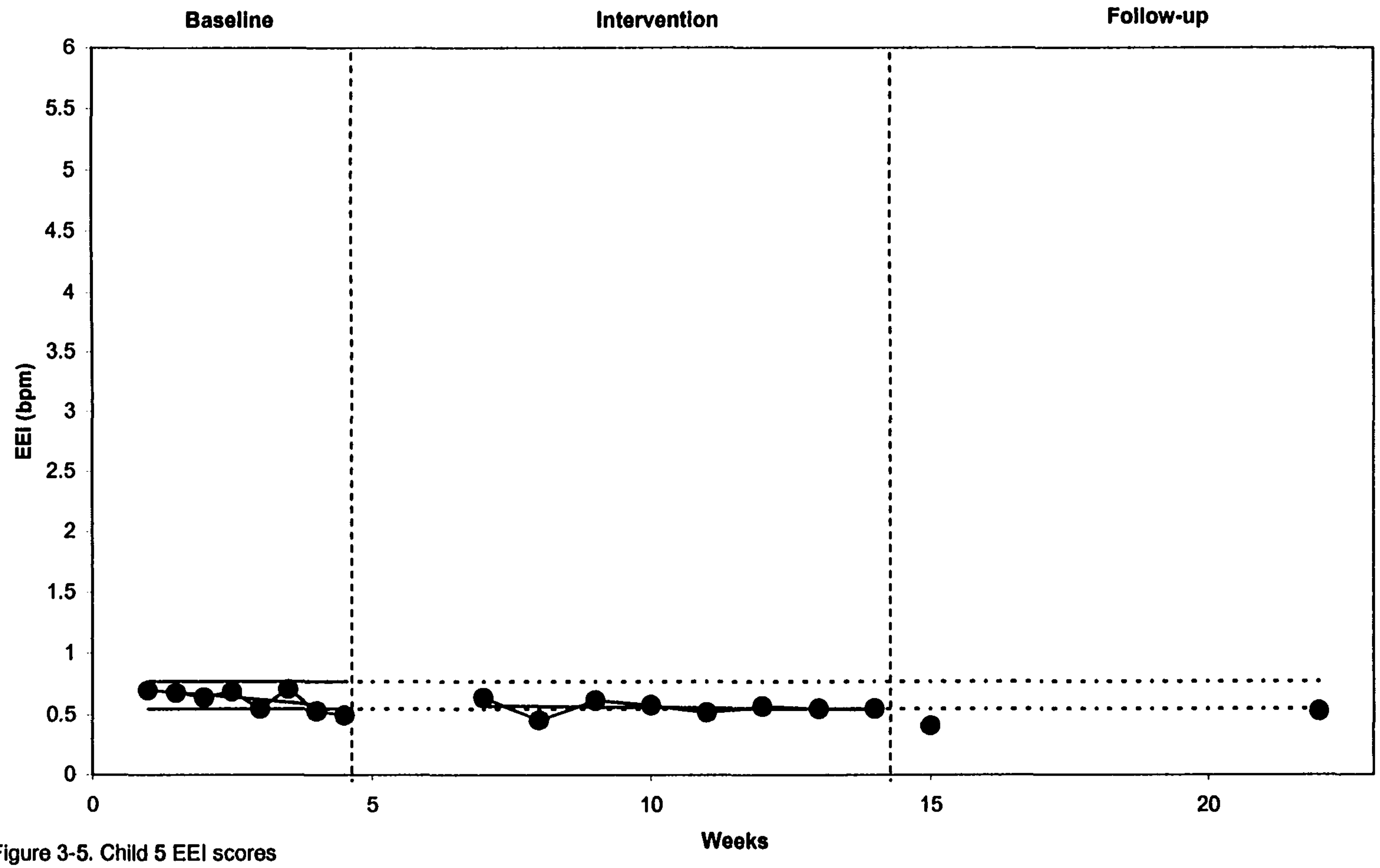

Figure 3-5. Child 5 EEI scores

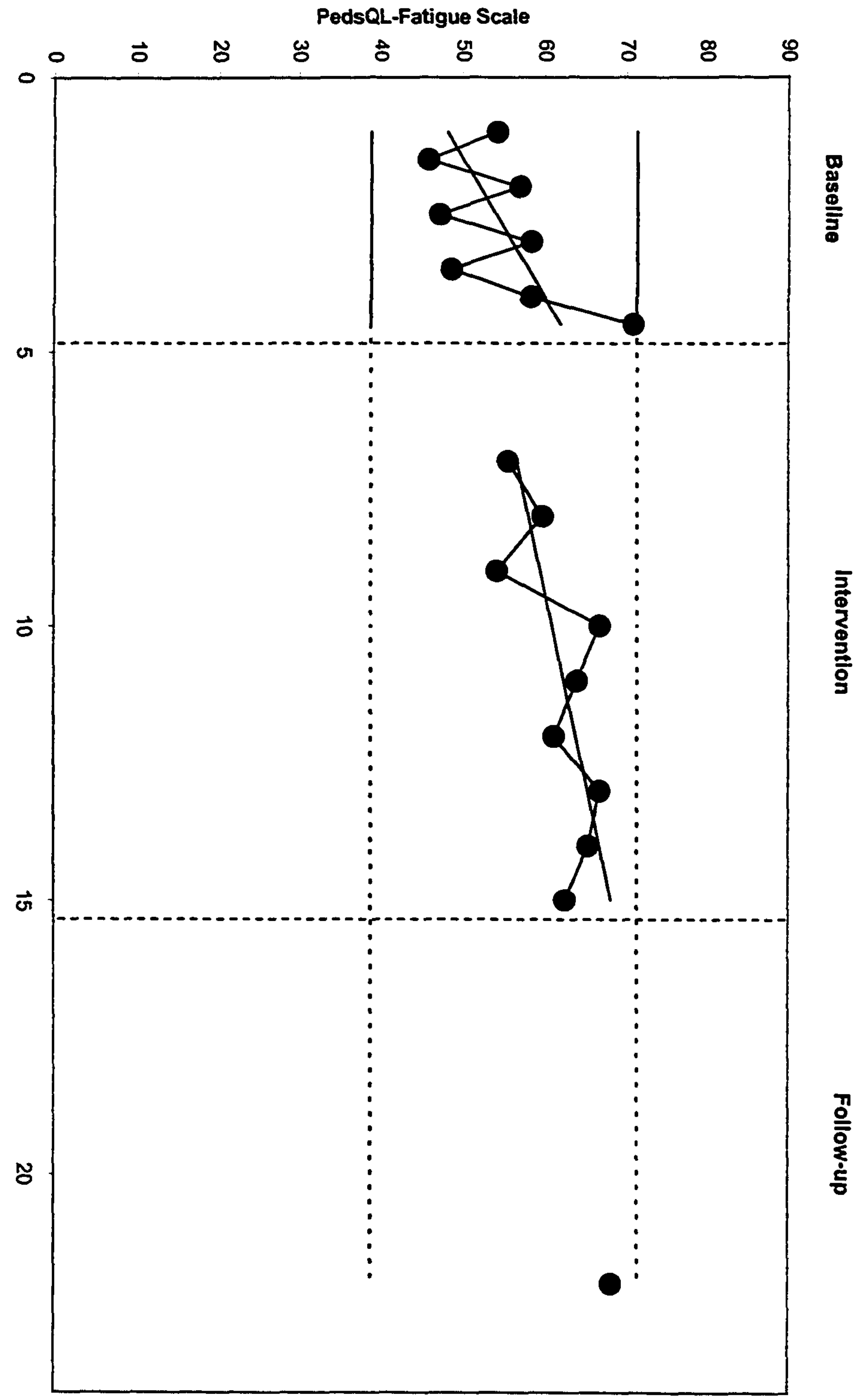

Figure 3-6. Child 1 PedsQL-Fatigue Scale scores

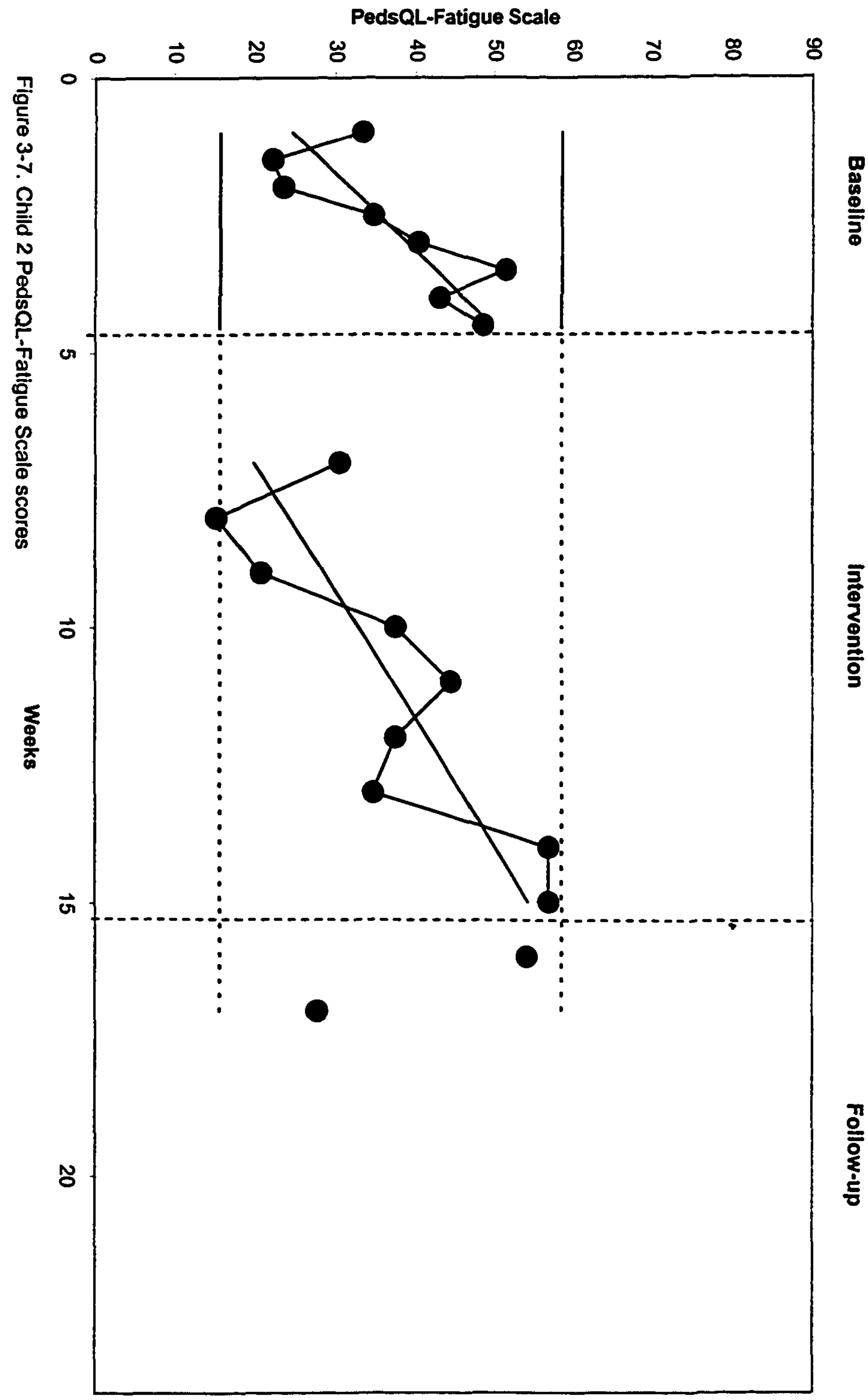

Figure 3-7. Child 2 PedsQL-Fatigue Scale scores

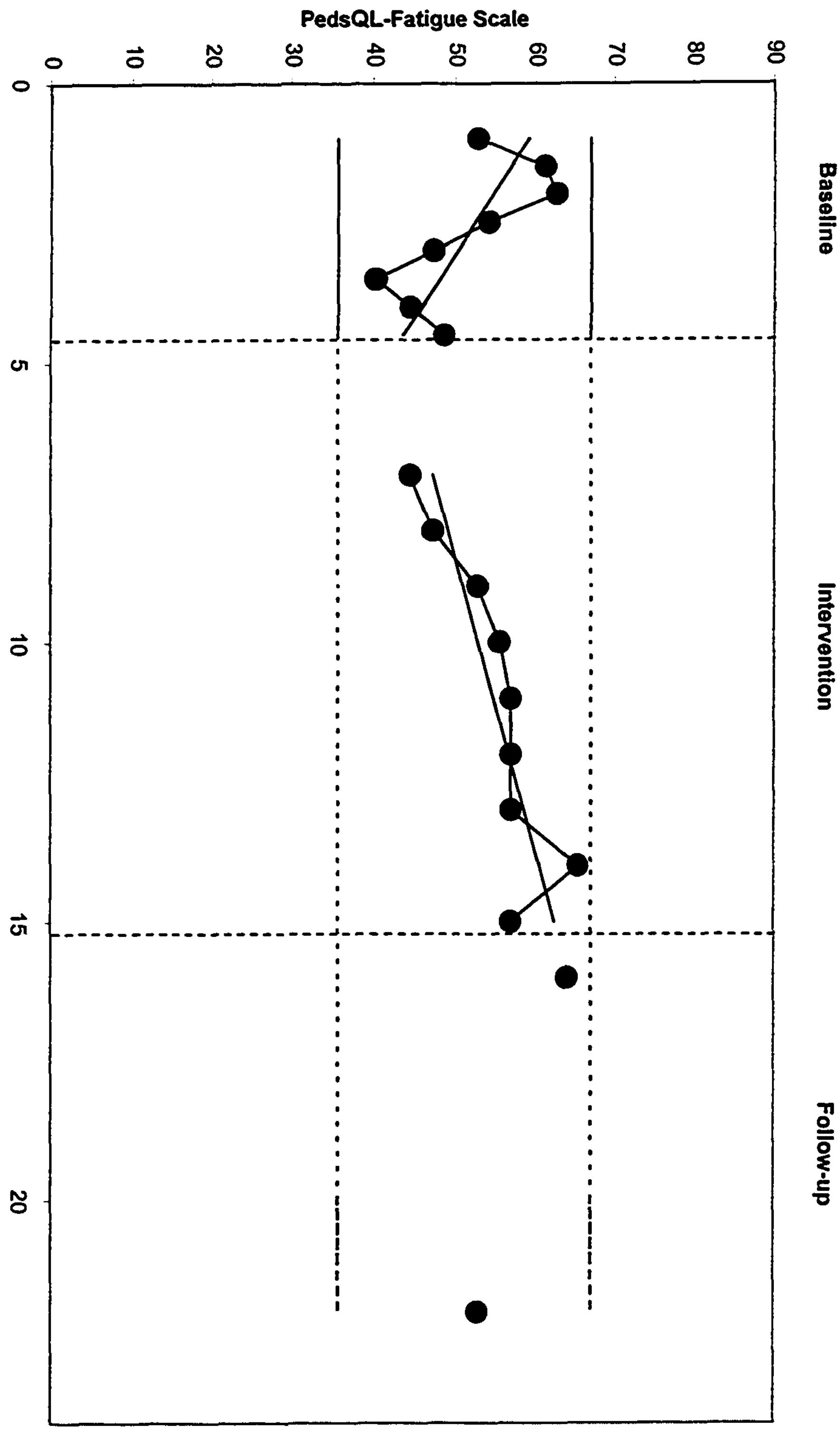

Figure 3-8. Child 3 PedsQL-Fatigue Scale scores

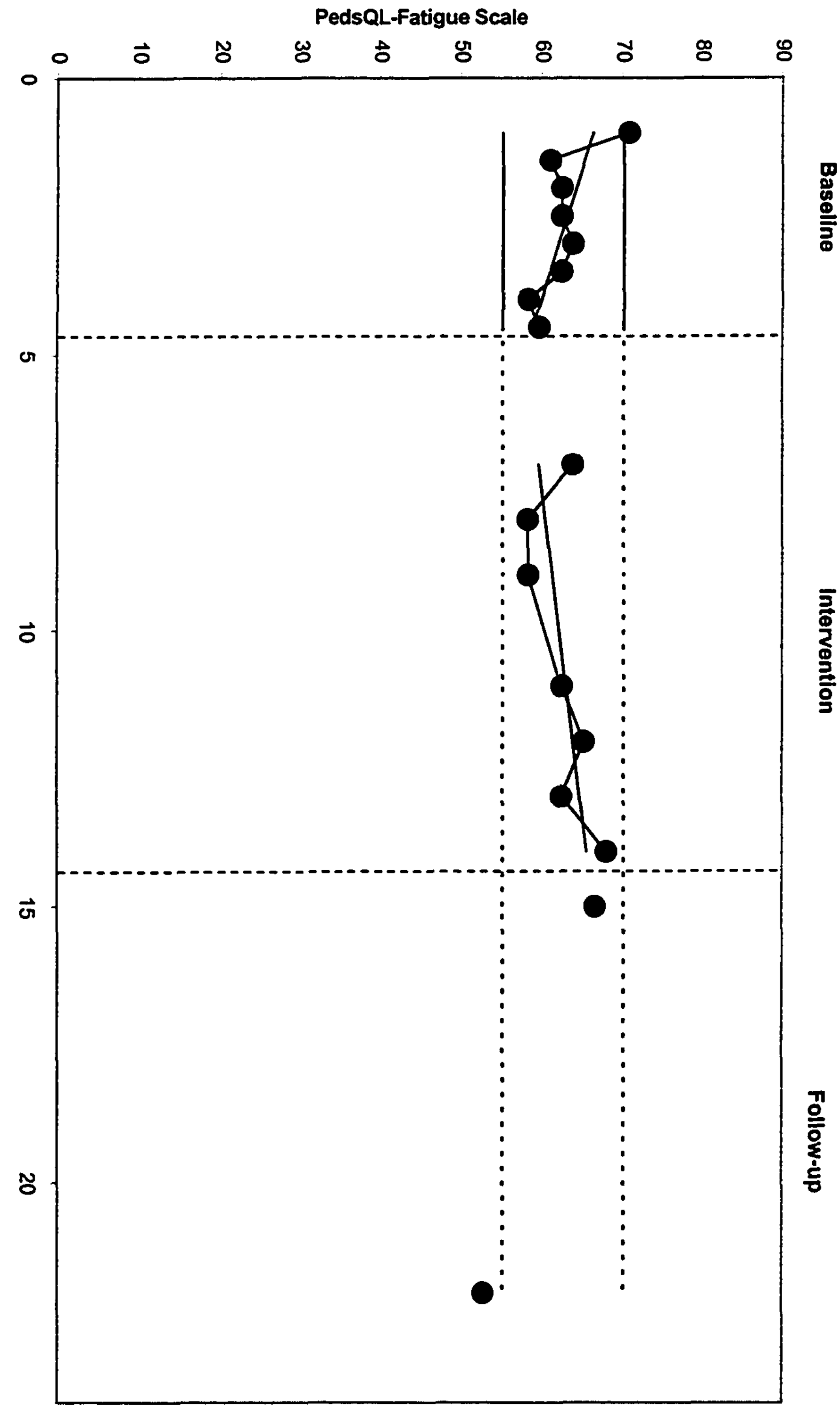

Figure 3-9. Child 4 PedsQL-Fatigue Scale scores

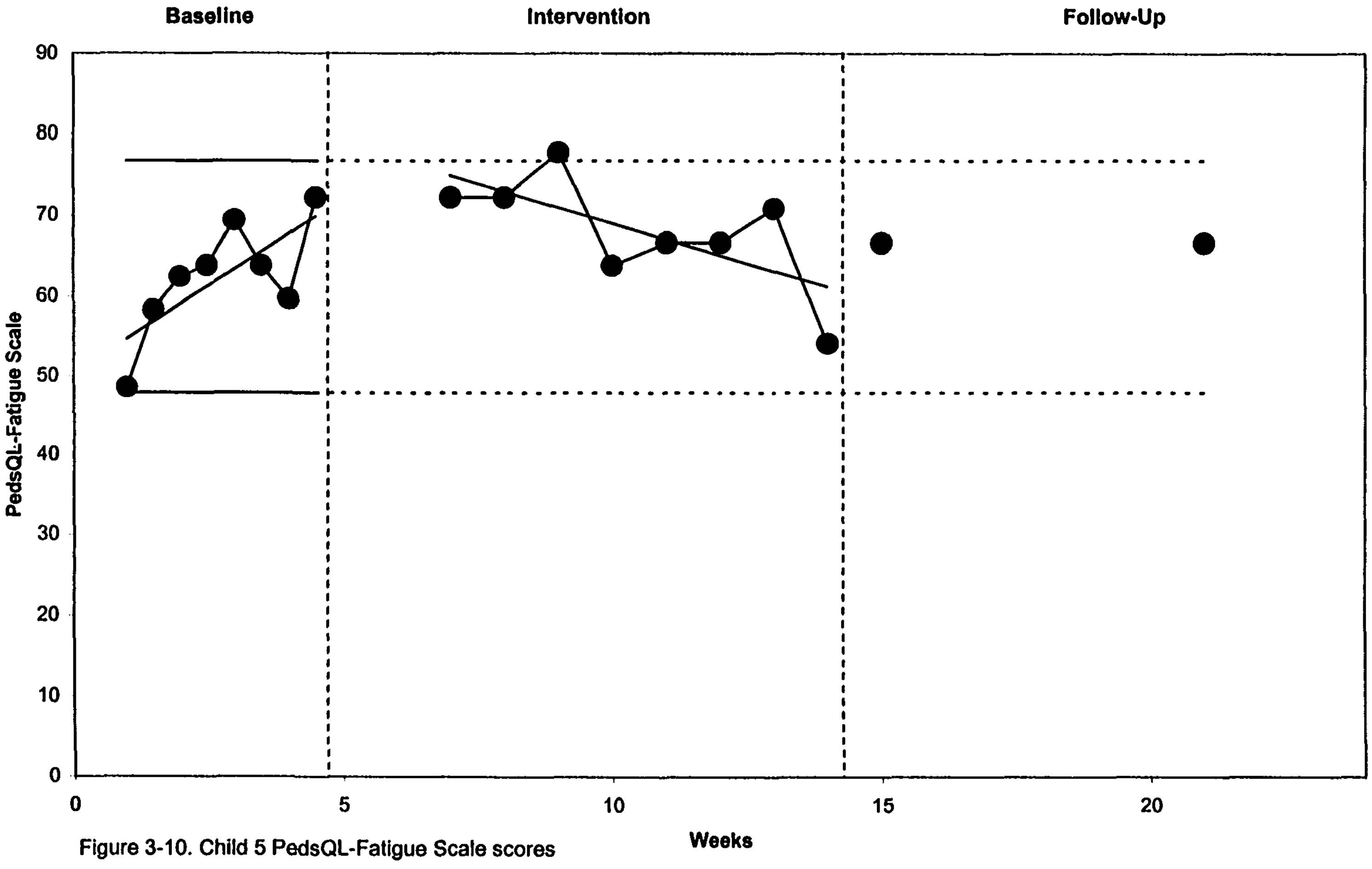

Figure 3-10. Child 5 PedsQL-Fatigue Scale scores

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CHAPTER 4

Conclusion

Summary of Results

The results of this study provide valuable information for clinicians and researchers regarding the effects of an aquatic intervention program for children with a diagnosis of cerebral palsy. Following a 12-week, three-times-a-week aquatic exercise program, five children with cerebral palsy demonstrated significant improvements in their level of perceived satisfaction and performance of gross motor skill performance. The physical intensity of the program did not adversely affect their fatigue levels during daily activities. Their heart rates and walking velocities, as measured by the Energy Expenditure Index (EEI) (Rose, Medeiros, & Parker, 1985), did not change substantively from the pre-intervention scores. The scores of all children on both the EEI and the Pediatric Quality of Life Mutidimensional Fatigue Scale (PedsQL-Fatigue Scale) (Varni, Burwinkle, Katz, Meeske, & Dichinson, 2002) were characterized by large variability.

Clinical Implications

We know from this study that children and their families can commit and complete an exercise program of a frequency and intensity to influence physical fitness. Typically, once-a-week interventions are considered “intensive” for school-aged children with cerebral palsy. In response to fitness programs that require a three-times-per-week frequency, therapists often express concern that families will not be able meet the time commitment. Families in this study, however, were able to attend the majority of the sessions, and were pleased with the format and content of the program. This suggests that short-term intensive physical fitness programs may be a viable therapy option to consider with children with cerebral palsy.

The results also suggest that community-based group activity interventions should be considered as a treatment option for children with cerebral palsy. Traditionally therapy has been delivered in a one on one format, but our experience using a group format suggest children may experience benefits that are unique to a group environment. Children's attention and motivation were easily maintained because of the variety and diversity of activities a group setting provides. Children enjoyed interacting with peers, and reported having 'fun' performing therapy that encouraged group participation, socialization, and competition. Because the study was based out of a community facility, children have the option to access and perform similar activities in the future. The study structure was also socially appropriate and socially relevant because many typically developing children ages 8-12 engage in group swimming lessons. Although children were performing exercises during the intervention, it seemed that children in the group saw the intervention less as therapy or exercise and more as a form of recreation involving play and competition with similar aged peers. Physical therapists could explore similar group formats to deliver therapy interventions.

Physical therapists also need to be cognizant of the possibility of natural variability in scores that children demonstrate on measure of physical fitness.

Clinically this suggests multiple testing rather than single point evaluation. Repeated testing may require more time for clinicians, but provides enhanced information regarding changes in the child's performance. Clinicians may need to re-evaluate their current assessment and evaluation practices to allow for multi-testing opportunities.

Dissemination of Results

The results of this study will be disseminated in a variety of ways. Chapter 2 and 3 will be submitted to peer-reviewed journals within six weeks of the thesis defense. The results of this study will also be presented to members of the Calgary Pediatric Interest Group and the Calgary Neuro Interest Group, as well as to interested members at the Alberta Children's Hospital and Calgary Youth Physiotherapy Clinic. One abstract or podium and poster presentations, using the contents of Chapter 2 and 3 will be submitted to the American Academy of Cerebral Palsy and Developmental Medicine in September 2005 in Orlando, Florida. Families of children participating in the study and who indicated an interest in the results will be provided summary of findings and a synopsis of information.

Implications for Future Research

More evaluation of physical fitness as an intervention in general needs to be done, especially to evaluate the impact of fitness interventions on aspects of activity performance and participation of children with cerebral palsy. There is virtually no other research data available regarding aquatic-based aerobic exercise intervention effects for children with cerebral palsy. Aquatic exercise is an attractive intervention alternative for children with cerebral palsy, and more research is required to guide clinical practice in order to use it as an appropriate and effective therapeutic modality. Concomitantly there needs to be evaluation and standardization of the outcome measures used to measure the effects of exercise intervention. To accurately interpret effects of fitness interventions on measures of energy expenditure and fatigue, a greater understanding of the reasons causing the intra-individual variability of the scores obtained is necessary. The effects of true variability and measurement error need to be evaluated. Studies using combined clinical and physiological measures of fatigue and aerobic function would help us to understand the mechanisms of the observed variability. In addition, research using measurement tools that are specific to the water environment would provide additional information as to the specificity of change following aquatic exercise interventions. Additional research regarding the required intensity, duration, and length of aquatic aerobic exercise is required to guide clinical practice in the safe and appropriate application of the intervention. Similarly, evaluating the effects of aquatic exercise for children grouped by similar ability would inform clinical practice regarding effective program parameters. Additional efforts to evaluate the potentially adverse effects of exercise intervention (both on-land and in-water) for children with cerebral palsy would contribute to a better understanding of the global effects of exercise interventions for children with cerebral palsy. Finally, it would seem that the relationship between observed changes in gross motor skill performance, changes in perceived performance and satisfaction of gross motor skill, and changes in levels of self-efficacy warrants further investigation. Information regarding these effects would benefit clinical practice by providing useful information regarding fitness interventions effects on the gross motor function of children with cerebral palsy.

T his study provides evidence that aquatic therapy is a feasible therapy intervention for children with cerebral palsy. More evaluation is needed to examine the physiological, functional and psychological effects of this underused intervention strategy.

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APPENDIX

Aquatic Exercise Program Details

Warm-up – 7-10 minutes

A variety of activities were employed for the group warm up. Children were led in a series of two to three minute games that focused on gradually increasing their movement and heart rate in the water. Listed are a variety of games and activities that were employed.

1. Freeze. Children were asked to follow the instructor in activities such as running on the spot, running for distance, side steps, step touches, high knee marching, karate kicks, tuck jumps, jumping jacks, slow to rapid movement of arms using 'water wheel' and 'bubble arm' patterns. When the instructor yelled: "freeze", children were asked to freeze their movement. If a child was caught moving the whole group performed 10 tuck jumps. (These were usually performed very quickly to keep the activity going and to add some fun to the action).
2. Add-on. The instructor and assistant started a set of activities to which children in the group added a movement or activity. The group performed all the activities in succession until each members of the group had two turns.
3. Shark Attack. Children were asked to run/swim around the pool at a comfortable pace. When they heard the words "shark attack", children were asked to swim as quickly as possible and sit on the edge (or hold on

to the edge) in order to be safe from the attacking shark. If any child was caught, all children performed ten quick tuck jumps.

4. Karate Master Says. This game is similar to the well-known Simon says game. Children performed activities following the verbal script "Karate master says". In this version, children performed karate moves in the water (chops, jabs, kicks, etc.).
5. Here, There, Where? Children lined up in the shallow end with enough space that they were able to touch the bottom. Children were directed here (right), or there (left), or where (jumping up and down).
6. Octopus. Children were asked to swim from one edge of the pool to the other. The instructor (octopus) stood in the middle and tried to catch the swimmers as they passed. The instructor remained in one spot and while children tried to swim past without being trapped by the "octopus" arm or leg.

Aerobic Sets – 20-30 minutes

Aerobic activity was implemented in a variety of ways through station work, lengths, aerobics, circuits, etc. Below are a variety of activities and aerobic games that were employed.

Activities:

1. On the spot running. To make the activity more difficult, arms were added such as lifting hands above head and back to shoulder level, or by stressing arm swing during the running activity.

2. High knee running. Once again, arms were added to make the activity more difficult.
3. Fast bubble arms. Arms were held under water in front of the body with elbows at 90 degrees repeatedly moving arms into external and internal rotation.
4. Fast wheely arms. Arms were held under water and repeatedly circling/rolling around each other.
5. Fast flying arms. Arms were held to the side performing repeated actions of shoulder abduction and adduction.
6. Fast chicken arms. Similar to flying arms only the elbows were bent.
7. Jumping jacks (arms under water)
8. Tuck jumps. Knees were tucked up to the chest from a standing position to a ball and return repeatedly.
9. Stride jumps. Step switches with the children jumping on each switch. Arms were added for complexity.
10. Heel kicks. For most children in our study, heel kick activities required having them hold onto the edge for stability. Alternating feet was a possibility for some children in our group who were able to perform the activity with adequate speed to attain a reasonable level of aerobic stress.
11. Kicking with hands on the edge.
12. Kicking sitting on the edge.
13. Kicking with hands on the edge pulling self in and out.

14. On the back kicking (with lifejacket support, head support, or no support depending on ability).
15. Front kicking with flutter board or inflatable kick board.
16. Length swimming independently (with life jacket emphasizing stroke with the arms on front/or on back).
17. High jumps. Swimmers were asked to jump as high as they could repeatedly.
18. Punch running. Children were to run on the spot, or in motion, punching the water or the air depending on the activity.

Aerobic Games:

1. "Fanatic sets". Fanatic sets involved fast paced movements in a successive circuit. Children would engage in a variety of the above listed activities for 10 counts of slow movement and then 10 counts of fast movement. Children would perform this cycle for four to five actions repeated in the set approximately four to five times. A 30 second rest was provided between each set.
2. Mixed length circuit. Children were encouraged to perform a series of consecutive length swimming activities including on-edge, stationary, and length activities to keep children engaged and interested. An example set:
    a. Thirty seconds of fast leg kicking sitting on the edge.
    b. Thirty seconds of fast leg kicking holding onto the edge.
    c. Push off the wall and swim to the end (15 meters).

d. Twenty tuck jumps.

e. Swim back to the edge.

f. Repeat four to seven times. Children would count the number of repetition by moving a popsicle stick or plastic bugs from one container to the other. They would have four to seven objects to start and would have to have moved all their objects over before the activity was deemed complete.

3. Giant Turtle attack. This was a length swimming activity used to encourage the children to swim continuously. In order to maintain their attention we added a "turtle attack". Children would swim up to 14 lengths where upon hearing "turtle attack", children would stand up and jump to dodge imaginary turtles that were swimming under their feet. Children returned to swimming upon hearing "safe to swim".
4. Submarine. This is a similar activity as giant turtle attack. In this game, children would swim 12 to 15 lengths of a 15 meter pool were upon hearing "Submarine" children would jump up and submerge themselves. Assistance was provided at the hips as required. Many children were wearing lifejackets for these activities therefore getting their head fully submerged was deemed their equivalent submarine.
5. "Fill the bucket". (Children in our study really enjoyed this activity). Children were sitting on the edge while the instructor held a bucket. Children were to kick very fast with as much splash as possible with the intent of creating enough splash to fill the bucket. Once full, each

child in the group was able to choose if they wanted the water dunked on their own head or that of the assistant instructor. The same activity was done with hands on the edge kicking. In this game, children were assisted in performing the activity by holding their hips close enough to the surface to allow their kick to create a splash.

6. Turbines and balls. Children started by sitting on the edge. Children dropped a ball in the water and kicked the water as hard and as fast as possible to move their ball as far as they could. Children then hopped in the water and retrieved their ball.
7. Throw and retrieve. Children also enjoyed sitting on the edge, throwing their ball as far as possible and then racing to get their ball as quickly as possible and return to the edge. Sometimes we played this as a race.
8. 12 length races. Swimmers enjoyed competition with their peers. Children in the program would all start on the edge and race through an eight to twelve length race to see who would get to the edge first. For children who were not as speedy as the other children, assistance was provided for a portion of the race so each child had a chance to win. The reward was having a bucket of water poured over their head. For some reason, the children loved working for this reward.
9. Rocket ship races. These races involved children starting on their back and their feet on the edge. Children would push off and kick on their back to the opposite edge as quickly as possible. Reward of

recognition was offered at the end. Usually the number of repetitions equaled twice the number of children in the group with each child winning at least one of the ten reps.

Walking Sets – 10 minutes

Walking activities were implemented in a variety of ways through station lengths, aerobic sets and games. Listed are a variety of activities that we employed. Assistance was provided to support the hips of some children who were unable to propel themselves through the water without support.

Walking games and activities:

1. Red Light/Green Light/Blue Light/Orange Light. This was just like the old adage game of red light green light.
    a. Red light = stop.
    b. Green light = walking.
    c. Blue light = running.
    d. Orange light = jumping.
2. How many steps to the treasure?. This game was similar to 'What time is it Mr. Wolf? Swimmers would ask the instructor how many steps to the treasure to which the instructor would reply a certain number of steps and the intended direction – forwards, sideways, and backwards. On the verbal cue "pirate attack", children would run as fast as possible to the edge without being caught by the pirate. Resistance can be applied during the walking component by holding flutter boards vertical.

3. Obstacle courses. Children were asked to walk forwards, backwards, sideways with or without resistance with intermittent obstacles such as stair climbing, swimming through an underwater hoola hoop (held above water for some children). Leg swings activities were often included in these activities to add variety at the end of the set. Repeated performance of this activity was counted by the children pouring one of four to six cups into a spinning wheel. When all their cups were empty they were deemed finished.
4. Spinner fun. Children would also practice walking carrying an empty cup to one side of the water, filling it up with colored water from a pitcher at the other side of the pool and returning to pool their colored water into the spinner toy. This was repeated until each child's pitcher was empty.
5. River walking. Children would line up two on one side with an instructor and two on the other side with an assistant. Children would walk forwards and back through a 'river' of turbulence created by the children along the side moving the water using 'bubble arm scull'.
6. 'Walk it' basketball. Children would take one of six balls, one at a time and walk to their respective floating basketball hoop. For children with limited upper extremity coordination and range. Assistance was provided to support children above the hoop to score.

7. Clean up basket ball. Once all the balls were scattered about the pool – children were asked to walk as fast as possible to retrieve the balls one at a time and return their to the start bucket.
8. Fox. Children would try and walk (with or without resistance) to the 'fox's den' (the lane rope) without getting caught. Every once in a while the fox would turn around and yell "FOX" – if any children were found moving – they had to take two steps backwards.
9. Mixed up baseball. Children were directed to find three floating objects scattered in the pool – a floating flutter board, a ball, and a hula hoop. Children were directed to walk/run as fast as possible to the directed floating object.
10. Octopus. As described above using walking only.
11. Shark attacked. As described above using walking only.

Cool down – 7-10 minutes

Often the walking activity was adequate to get the heart rates down of children in the group. We concluded each session with deep breath and bubble blowing following by self-stretches to the calf, hamstring, quad, adductors, and hip flexors.