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Clinical Study

The Effect of Aquatic and Land-Based Training on the Metabolic Cost of Walking and Motor Performance in Children with Cerebral Palsy: A Pilot Study

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Aim. To evaluate the effects of aquatic (AQ) compared to a land-based (LB) intervention programs on metabolic cost of walking (MCW), gross motor function and locomotor performance in children with cerebral palsy (CP). *Methods*. Eleven children with spastic diplegic CP completed this study, six in the AQ (5.2 ± 1.45 yrs) and five in the LB group (4.1 ± 1.33 yrs). MCW derived from Oxygen uptake (VO_2) measured with a Cosmed K4 device and walking speed at steady state. Additional measures included the 10-m test, Gross Motor Function Measure (GMFM), and Pediatric Evaluation Developmental Inventory (PEDI). Non-parametric statistics were used to analyze change in each group. *Results*. The AQ group significantly decreased MCW ($Z = -2.2$; $P < .05$) and increased steady state walking speed ($Z = -2.2$; $P < .05$). Both groups significantly increased 10-m walking speed ($Z = -2.2$; $P < .03$, and $Z = -2.02$; $P < .05$, resp.). The LB group exhibited moderate to large effect sizes in 10-m self-selected and fast walking speeds (Cohen's $d = 1.07$ and 0.73, resp.). *Conclusion*. Our findings suggest that Both AQ and LB programs were effective in improving 10-m speed, while the AQ training also improved the MCW of walking at steady state in children with spastic diplegic CP.

1. Introduction

Cerebral palsy (CP) is defined as a group of permanent disorders of the development of movement and posture that cause activity limitation, and are attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain [1]. Compared to children without disability, children with CP exhibit a variety of primary and secondary functional restrictions, including (a) exaggerated muscle tone, present in 75% of all cases, interfering with the execution of controlled isolated movements [2, 3]; (b) reduced range of motion in the extremities during gait [4]; (c) reduced muscular strength [2, 5]; (d) deficits in aerobic and anaerobic capacity [6, 7]; (e) reduced respiratory function [8]. All these factors affect the ability of children with CP to walk, which is a primary rehabilitation concern of parents and clinicians.

Children with CP expend more energy during walking than typically developing children, requiring as much as three times normal values [9, 10]. This increased energy expenditure has been linked to excessive muscle coactivation during walking, increased cadence, and double support time, suggesting poor coordination and resulting in a higher oxygen uptake (VO_2) in these children compared to children without disability [9, 11, 12]. The increased O_2 cost of locomotion may be the main determinant of the early onset of fatigue in this population [11]. If this higher energy cost of walking is not decreased, it is likely that these children will reduce their participation in motor activities, evoking an increase in body weight and adiposity, and thus further limiting their activity rate [13, 14]. For example, daily step counts [15] and weekly participation in community physical activities [16] have been considerably reduced in children with CP compared to typically developing children. The latter two studies also demonstrated that children with lower functional levels according to the Gross Motor Functional Classification System [17] (GMFCS V to III) had lower participation rates compared to children at GMFCS levels I or II.

Community exercise and physical fitness programs have been found effective in increasing walking ability of children with CP [14, 18, 19]. Specifically, strength training [18, 20, 21] is among the most often practiced approaches; however, in spite of gains sometimes observed in strength, the suitability of this training to promote walking in children with CP has only limited support [22, 23]. Swimming and aquatic therapy have been suggested as beneficial activities for children with motor deficiencies, including those with CP, when applied at very early ages [24–33].

The unique benefits of the aquatic environment for children with CP have been reported elsewhere [29, 34]; yet the specific mechanisms that might improve function in participants with neuromotor disorders have not been described. Research with able bodied and lower limb impaired participants indicated effects of aquatic training [34, 35]. Svedenhag and Seger [36] showed that heart rates were lower for a similar VO_2, while the blood lactate levels and perceived exertion were higher, after training in the water. Several phenomena appear to contribute to these differences: (a) the increased resistance to movement initiation and continuation in the water, caused by the water viscosity, may add to the peripheral component of muscle activation during an aquatic compared to a similar land-based activity [36]; (b) this increased water resistance, together with the buoyancy effect of water, suppressing antigravity muscular work, appears to reduce muscle blood flow and decrease the arterio venous oxygen difference [37]; and (c) movement patterns evoked during running in water included a greater proportion of arm work compared to similar exercise on land [36].

Based on these phenomena, it is likely that children with CP could engage in physical activity for a longer duration in the aquatic environment, while conditioning more muscle groups before reaching fatigue, compared to exercising on land. Yet, despite of the opportunities provided by the aquatic environment for improving physiological and motor performance, very limited research has been documented thus far measuring specific outcome effects with regard to walking. Recent aquatic training studies in small samples of children with CP reported some evidence with regard to improving walking endurance [24, 25, 28], functional mobility [24, 28], and strength [24]. However, these studies used no comparative treatment conditions or metabolic measurements.

Therefore, the purpose of this study was to compare the outcomes of an aquatic (AQ) and a land-based (LB) training program on (a) the metabolic cost of walking and (b) gross motor function and locomotor performance in young children with CP.

Table 1: Individual criteria of participants across the aquatic and exercise intervention groups at the pretest.

ID	Gender	Age (Yrs: M)	Mass (kg)	Stature (cm)	GMFCS
Aquatic exercise group					
1	M	03.05	13.6	105	I
2	M	04.10	18.4	111	III
3	M	05.02	19.4	111	II
4	M	05.04	14.3	111	II
5	F	06.05	20	110	II
6	F	06.0	16	100	III
Land-based exercise group					
1	F	06.05	16.5	116	III
2	F	04.08	14.7	108	II
3	M	03.11	17	108	I
4	F	04.03	12.8	110	II
5	F	04.03	12	100	III

2. Methods

The study was designed as a two-group training project with convenience sampling. Children with CP from a special kindergarten comprised the AQ group and those from a similar kindergarten in another part of the same city the LB group.

2.1. Participants. Seventeen children (nine in the aquatic intervention group and eight in the land based exercise group) with cerebral palsy (spastic diplegia) ages 3–6 entered the study. All children met the following inclusion criteria: (a) medical diagnosis of cerebral palsy of the spastic diplegic type based on a physician's assessment; (b) no other medical complications, such as seizures; (c) had an ability to comprehend instructions; (d) placed in a special education setting supervised by the Israeli Board of Education; (e) did not have any medical procedures involving the lower limbs in the last 12 months (including casting or Botulinum toxin injections); (f) able to walk three minutes at a self paced speed; (g) had functional performance levels between I–III of the GMFCS [17]; (h) were compliant to the metabolic measurement procedure; (i) participated in at least 60% of the practice sessions. Posttest measures of three children from the land-based exercise group ($n = 8$) were not collected because of medical conditions and attendance ($n = 1$ seizure attacks; $n = 1$ botulinum toxin injections; $n = 1$ attended only 30% of the sessions). Three participants in the AQ group were noncompliant for using the metabolic measurement equipment, and had to be excluded. Thus the final sample included five children in the LB exercise group and six children in the AQ group. Individual criteria of the participants in the final sample of the aquatic and the land-based intervention groups are described in Table 1. The mean ages of the aquatic and the land-based exercise groups were 5.2 ± 1.45 yrs and 4.1 ± 1.33 yrs, respectively. Most of the participants in both groups were classified as GMFCS II and III. There were two females in the AQ group and four in the LB group. The study was approved by the scientific committee of the Board of Education, the Medical Ethics Committee for approving research in humans, and the School Board of the participating kindergartens. Parental informed consent was signed for each participant.

2.2. Procedures

2.2.1. Metabolic Cost of Walking. Direct metabolic measurement while walking was performed by means of the Cosmed (Rome, Italy) K4 b2 system. This is a portable breath by breath metabolic measuring and recording system. The K4 b2 system uses a facemask, with turbine flow meter and oxygen electrode. The child carried a gas sampler and a telemetry transmitter, together with a battery pack, which were carried using a special harness. The total weight of the carried equipment was about 800 g. A mobile receiver and data processing system were carried separately by a technician. The K4 b2 has been validated and found reliable [38], and has been used with children with and without disabilities [39].

This procedure was favored over stationary treadmill testing, mainly due to the fact that it enables the child to be tested while walking, self paced on the floor, with his or her own locomotor aids, rather than on the treadmill, which is an externally paced device for which specific training and habituation are required [9]. During earlier pilot testing, it was identified that if the child was asked to perform turns while walking, heart rate (HR) values dropped quickly, in some cases to resting values. Therefore, in order to determine reliable oxygen uptake values for continuous walking performance, a setup was chosen in which the child walked in an elliptical course until reaching steady state values; from this point in time he or she continued to walk in a straight line, without having to change direction for a distance of 34 meters (the longest straight line in the gymnasium). The amount of time it took the child to reach steady state values differed between participants depending upon their level of function. Individualized metabolic responses were tracked using the real time graphic representation of VO_2 and VCO_2, enabled by means of the K4 b2 metabolic cart. This device produced data points breath by breath, which averaged every 20 sec. Steady state (SST) was determined when VO_2 ceased to increase in response to exercise for longer than three consecutive 20 sec intervals (one minute in total), and then the straight line walking was commenced. We adapted the procedure of Unnithan and colleagues [12] to the context of this study and measured three consecutive intervals, each of 20 sec, summing up to one minute duration from the start of the 34 m straight line walk. These three intervals were then compared to qualify for SST, applying the criterion of 15 mL/min maximal change from one 20 s interval to the next.

The individual fitting procedure was initiated by fitting the child with a Polar (Electro, Finland) S610 heart rate monitor. Following this, the metabolic apparatus was fixed. Once the mask was properly adjusted, the child was asked if he or she was comfortable. The measurement started when the child was asked to sit for a period of three minutes or until predictive resting values of HR were observed. Following the rest period, the child was asked to walk at a self paced speed with shoes and walking aids following the oval track until steady state values were observed by the technician. As the continuous metabolic responses were observed, the child was assisted to the straight line and continued to walk the 34 m without stopping. At the end of this line, the child was seated for recovery until HR values reached the resting values. Metabolic cost of walking (MCW) ($\text{mL}\cdot\text{meter}^{-1}$) was calculated by dividing the oxygen consumption (VO_{2}–mL/min) by the speed (V-m/min), that is, the time it took to travel the 34 m. In addition, we calculated the time it took each child to achieve SST (i.e., the first of the three 20 sec intervals with steady VO_2 values) after commencing walking. An exercise physiologist technician administered the test together with two adapted activity professionals.

2.2.2. 10 Meter Walk. This test was selected because it is one of the most popular activity outcome measures for children with CP [23, 40], demonstrating a test retest reliability of 0.81 (95% confidence interval 0.65–0.90) across participants [41]. Each child did a practice walk where no data were recorded, in order to become familiarized with the procedure. The child was then asked to walk a 14 meter distance (an extra two meters were added at the beginning and the end of the runway to minimize the effects of acceleration and deceleration). upon being given a verbal cue, under two conditions: (a) "walk as fast as you can without running"; and (b) "walk at your regular speed." One observer used a stopwatch to measure the time it took the child to walk across the 10 meter distance starting when the foot first touched the starting line and the foot last contacted the end of the ten segment line. Time was recorded for each trial. The child performed three trials under each condition. The children rested between trials until HR was within 10% of the resting values [42]. Speed (m/min) was calculated by dividing the 10 m distance by the time it took to cover that distance.

2.2.3. Gross Motor Function Measure. Physiotherapists in each kindergarten administered the 66 item version of the Gross Motor Function Measure (GMFM) [43]. Prior to administering the first evaluation, the physiotherapists attended a workshop supported by the Board of Education, which trained them to administer the GMFM. The GMFM is a standardized observational instrument for children with CP and head trauma developed to measure change over time. The GMFM was administered to all participants in five dimensions: A (lying and rolling), B (sitting), C (crawling and creeping), D (standing), and E (walking, running and jumping). Scores on each dimension were using a score sheet, providing each child with percentage scores on each dimension according to the GMFM manual [43].

2.2.4. Pediatric Evaluation of Disability Inventory (PEDI). The PEDI [44] is a standardized instrument for evaluating functional performance. Its reliability and validity has previously been established [45, 46]. It has been proved efficient in

Table 2: Descriptive outcomes of VO_2 (mL/min) during three consecutive intervals of 20 sec and percentages of the last intervals represented by the two first intervals during walking the 34 m line.

		Aquatic			Land-based		
	Sec	0–20 s	21–40 s	41–60 s	0–20 s	21–40 s	41–60 s
Pre-test	Mean	415.06	430.62	404.15	383.36	395.86	390.89
	SD	113.54	98.20	86.40	103.83	110.19	108.73
	% of 41–60	103	107		98	101	
Post-test	Mean	438.03	449.25	447.54	369	384	392
	SD	119.36	122.81	114.01	76.28	75.06	118.37
	% of 41–60	98	100		94	98	

documenting change in function after interventions [47] in children with CP or related neurological impairments. The PEDI is divided into three content areas: (a) self care; (b) mobility and (c) social function. In our study, only the mobility and self care domains were administered. The child's attending physical therapist conducted the mobility domain and the attending occupational therapist conducted the self care domain of the interview. These professionals were unaware of the study purpose and group assignment.

2.3. Intervention. Children in the AQ participated in an ongoing adapted aquatics program for children of the participating kindergarten. Children in the LB exercise group did not receive aquatic sessions, but maintained a land-based exercise program. Post-test measures were recorded after a four-month intervention period, ensuring at least 32 sessions for the participants in each group. All outcome measures were recorded within a three-week period at the pre- and post test measurements. Participants used the same mobility aids during the pre-and post tests. Their weight and stature were measured during each of the test periods.

2.3.1. Aquatic Intervention. The adapted aquatics program consisted of two weekly individualized 30 min sessions in an indoor heated therapeutic swimming pool (water temperature set at 33-34°C). Each child was assigned to a trained instructor throughout the program. Goals were individually determined, in cooperation with the attending physiotherapist, to meet the specific needs of each participant. A multidisciplinary approach was applied in determining program goals and objectives, with an emphasis on improving functional abilities in the water environment in reference to the Aquatic Independence Measure (AIM) [48] and the 10 point program of the Halliwick concept [49, 50], which includes water adjustment skills, longitudinal rotations, sagtital rotations, and swimming skills. Each session consisted of three parts: (a) the first five minutes, consisting of a structured group activity with six children and their instructors. This part encouraged mental adaptation to the aquatic environment and was accompanied by rhythmic children's songs that were repeated throughout the program; (b) the second part, consisting of a 20 minute period during which children practiced individually or in pairs according to treatment goals according to the Halliwick concept; (c) the final five minutes, consisting of group activities with children's songs, aimed at ending the session and disengaging the children from the aquatic environment. Throughout the sessions the children were immersed in water at chest level, thus bearing 25% of their body mass [31].

2.3.2. Land-Based Intervention. Children in the land-based exercise group were placed together in one kindergarten. The children received 30 min of individualized land-based activities twice a week, as part of their educational curriculum, comprised of (a) an additional physiotherapy session once a week which included 15–20 min of full weight bearing treadmill exercise at a comfortable individualized speed (ranging between 0.5–1.0 $\mathrm{km\cdot hr^{-1}}$), enabling the child to walk continuously in full weight bearing conditions and stretching exercises, and (b) an adapted activity program once a week. An exercise instructor supervised the adapted activity program. The program objective was to improve fundamental motor skills, such as walking, stepping over obstacles, climbing, and catching and throwing objects.

Both programs followed an age appropriate approach with an intermittent intensity phases that included four to five bursts of intensive and relaxing activity of two-three minutes each, preceded with a warmup and followed with cooling down of five minutes. According to sample measurements using Polar heart rate (HR) monitors, the HR during the high intensity phases reached 80% of predicted maximal heart rate.

2.4. Statistical Analysis. Kolmogorov-Smirnov tests were used to challenge the assumption of normal distribution, and found no threat to parametric statistics. In each group nonparametric statistics were used. Mann Whitney tests were used to compare between groups at the pretest, and Wilcoxon matched pairs signed ranks tests compared pre- and post tests in each group. Percent gain and effect size of the pre to post test outcomes within each group were also calculated [51]. Kruskal Wallis nonparametric ANOVA and descriptive statistics were used to compare the three 20 sec intervals during SST. An alpha level of 0.05 was selected.

3. Results

Mann-Whitney tests did not indicate significant differences between groups at the pre test ($P < .05$).

3.1. Cardiorespiratory Function and Metabolic Cost of Walking. Table 2 depicts three consecutive averaged values of VO_2 measurements starting at the 34 m straight line, and the percentages that the last interval represented out of the two first intervals during walking the 34 m′ line (range 0–7%). The mean VO_2 consumption between intervals did not differ more than 15 mL/min and did not prove significant in the ANOVA. These results suggest that SST was achieved while measuring the VO_2 consumption while walking, both at the pre- and post tests.

Table 3 presents the mean, standard deviations, and pre-to-post gain percentage values of the cardiorespiratory variables across time and group. Mann-Whitney tests did not show significant differences between groups in any variable at the pretest measurement. The Wilcoxon tests, performed in each group separately, revealed different time effects across groups. MCW significantly decreased in the AQ group ($Z = -2.2$, $P < .05$), unlike the LB group that also decreased but did not change significantly ($Z = -0.135$; $P > .05$). Speed during the SST measurement was also different for both groups (see Figure 1). While the LB group maintained its performance, the AQ group significantly improved it after the training period ($Z = -2.2$; $P < .05$). The decrease in MCW and increase in walking speed during the SST in the AQ group also demonstrated moderate to large effect sizes (Cohen's $d = 0.70$, and 1.01), compared to small or no effect sizes in the LB group (Cohen's $d = 0.22$ and 0.05, resp.). Time to SST did not change significantly. However, effect size between the pre- and post test values were larger in the AQ group ($Z = -1.72$; $P < .1$; Cohen's $d = 1.04$) compared to the LB group ($Z = -0.135$; $P < .9$; Cohen's $d = 0.32$).

Table 3: Descriptive values of cardio-respiratory outcomes measured during the last min of the 34 m continuous walk for assessing the metabolic cost of walking.

	Pre test		Post test		% change
	Mean	SD	Mean	SD	
Aquatic group					
VO_2 ($L\cdot min^{-1}$)	0.41	(0.10)	0.44	(0.11)	7.9
VO_2Net ($L\cdot min^{-1}$)	0.19	(0.095)	0.22	(0.096)	11.4
VO_2 ($mL\cdot kg^{-1}\cdot min^{-1}$)	24.07	(4.50)	26.17	6.27	8.7
MCW ($mL*m^{-1}$)	15.54	(9.16)	10.57	(4.18)	−32
TTSST (sec)	229.5	(97.12)	153.33	(37.24)	−33.2
VE ($L\cdot min^{-1}$)	15.14	(2.71)	15.5	3.88	2.4
VE/VO_2	37.94	(5.76)	35.47	(2.87)	−6.5
RER	0.86	(0.09)	0.88	(0.06)	0
HR ($Beats*min^{-1}$)	149.7	(11.7)	146.6	(29.0)	−2.1
Land-based group					
VO_2 ($L*min^{-1}$)	0.398	(0.096)	0.400	(0.08)	0.5
VO_2Net ($L*min^{-1}$)	0.186	(0.067)	0.184	(0.081)	−1.1
VO_2 ($mL*min*kg^{-1}$)	24.89	(6.59)	27.08	(4.63)	8.8
MCW ($mL*m^{-1}$)	17.66	(14.57)	15.0	(8.44)	15.1
TTSST (sec)	204.8	(59.54)	193.8	(39.71)	−5.4
VE ($L*min^{-1}$)	13.36	(2.82)	12.26	(2.47)	−8.2
VE/VO_2	33.93	(4.58)	30.75	(3.81)	−9.4
RER	0.875	(0.06)	0.80	(0.09)	−8.8
HR ($Beats*min^{-1}$)	141.8	(4.46)	146.7	(15.58)	3.5

Abbreviations: VO_2: Oxygen Consumption; VE: Ventilation; TTSST: time to steady state; RER: Respiratory Exchange Ratio; determined by dividing VCO_2 produced by VO_2 consumed; HR: Heart Rate.

3.2. Locomotor Performance Measures. Table 4 represents the mean and percentage values of the locomotor performance measures. Outcomes of the Wilcoxon tests depicted a significant increase in both the fast and self-selected pace 10 m walk in the AQ group ($Z = -2.2$; $P < .03$ in both variables), but only in the fast pace of the LB group ($Z = -2.02$; $P < .05$). However, the effect sizes were larger in the LB group at the fast and the self selected pace (Cohen's $d = 1.07$ and 0.73 resp.), compared to effect sizes below 0.5 in the AQ. No significant differences between pre to post measurements were observed in the GMFM or the PEDI. It should be noted, however, that GMFM and PEDI utilize ordinal compared to interval scales in the 10 m walk test and the metabolic measurements. Ordinal scales are less sensitive to change than the interval scales, and differences between groups might be less likely observed using a P value of 0.5.

4. Discussion

This study attempted to measure the effects of AQ compared to LB interventions on the MCW and locomotor performance in young children with CP. Improving locomotor speed and endurance is expected to enhance the ability of children with CP to participate in school physical activities, since it is likely that teachers and peers would allow them to be included in more formal and informal motor activities. In the following sections the metabolic and locomotor performance outcomes will be discussed.

4.1. Metabolic Cost of Walking. The first aim of our study was to investigate the effect of the aquatic compared to land-based training on MCW. The main outcome in our small and young sample of children with spastic diplegic CP revealed that AQ intervention seems to be favorable for decreasing MCW. This appears to be a result of increasing walking speed, while maintaining the amount of oxygen consumed during the submaximal walking trial. Participants of the AQ group also decreased the time required to achieve steady state values at post test. While a quantification of the mechanisms underlying performance buildup was beyond the scope of this study, our findings may reflect benefits of the warm water temperature, the viscosity, and the buoyancy effect provided by the aquatic environment. The water viscosity prolongs falling time and enables the participants to experience movement patterns that allow the center of gravity to be momentarily outside the base of support without fearing to fall. These factors have been reported to increase performance, such as in muscular endurance, neuromuscular coordination, and aerobic capacity [25, 32, 52]. In addition, the lower heart rate and oxygen uptake common during exercise in the water compared to exercise on land

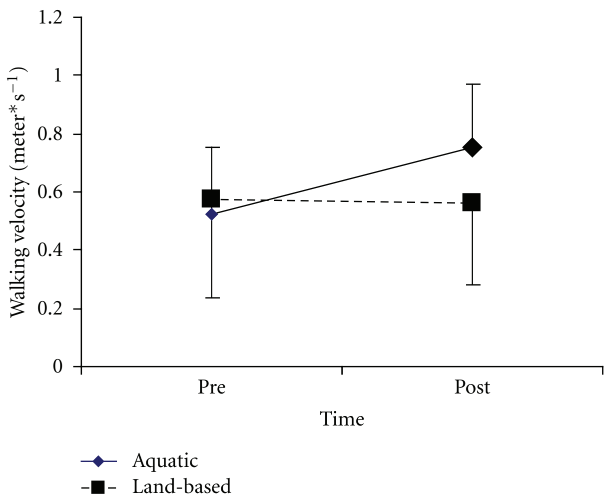

Figure 1: Comparison of pre to post walking speed during the 34 m walk across groups.

Table 4: Descriptive values of activity outcomes.

	Pre test		Post test		% gain
	Mean	SD	Mean	SD	
Aquatic exercise group					
10 m FV (m$*$sec^{-1})	0.94	0.41	1.18	0.50	21
10 m SSV (m$*$sec^{-1})	0.61	0.26	0.72	0.30	15
GMFM sum (score)	62.60	8.20	61.80	9.20	−1
GMFM D, E (score)	61.20	7.22	67.10	17.66	10
PEDI sum (score)	58.93	4.27	62.20	7.69	6
PEDI pt (score)	67.05	15.76	73.28	15.40	9
Land-based exercise group					
10 m FV (m$*$sec^{-1})	0.70	0.31	0.94	0.35	27
10 m SSV (m$*$sec^{-1})	0.47	0.29	0.76	0.25	38
GMFM sum (score)	61.34	10.12	62.34	11.52	2
GMFM de (score)	61.21	10.34	62.00	12.23	1
PEDI sum (score)	57.16	2.03	56.30	1.80	−2
PEDI pt (score)	67.64	12.64	59.92	17.30	−11

Abbreviations: FV: fast velocity; SSV: self selected velocity; GMFM: Gross Motor Function Measure (Score range from 0–198); PEDI: Pediatric Evaluation of Disability Inventory (Score range from 0–100).

[36, 52] may have increased time on task and intensity of exercise throughout the intervention session. The increased body weight support and relaxing effect of the aquatic environment may have facilitated a reduction of spasticity and an increase in muscular strength, thus allowing the child to initiate movements that are restricted on land.

In a recent systematic literature review on exercise programs for children with CP [14], only one study with seven participants, ages 12–20, proposed evidence supporting a decrease in MCW [53]. This program incorporated heavy resistance training pertaining to 80% of 1RM in lower extremity and trunk muscle exercise three times per week. However, MCW was not directly measured in this latter study but indirectly predicted through the Energy Efficiency Index derived from HR and velocity. Our study appears to be the first intervention study recording an improved MCW using direct calorimetry in young children with CP.

4.2. Locomotor Performance Measures. The second aim of the study was to establish the effects of an aquatic compared to a land-based intervention on gross motor function and locomotor performance. Previous research [54] has revealed results supporting a significant effect of a land-based exercise programs on walking velocity during the 10 m walk test in children with CP. In our study, an improved performance in the 10 m walk test was apparent in both groups. However, the AQ group showed significant differences both in the fast and self paced speed of the 10 m walk, while the LB group showed significant improvement in walking the 10 m distance only in the fast pace. However, the percent gain in the fast pace was larger in the LB compared to the AQ group (38% and 15% resp.). This outcome may be a result of the specific water viscosity reported earlier that does not support the development of fast movements, which are needed while walking at a fast pace. In addition, the aquatic environment provided in our study was designed for practicing at about 25% body weight rather than at full weight bearing, and therefore was a less task specific practice compared to treadmill walking and movement activities performed during the land-based intervention.

Our study did not reveal any significant improvement in GMFM and PEDI results in either group. The lack of transfer from the potential metabolic and speed related gains observed in other activity domains may be due to the reduced sensitivity of the GMFM and PEDI ordinal scales compared with the interval scales used for MCW and speed measurements. Other aquatic intervention studies reported varied results. Thorpe and colleagues [33], using an ABA design, found improvement in GMFM following a ten-week program of resistive aquatic exercise. Fragala-Pinkham and colleagues [25] did not find changes in the PEDI score after an aquatic aerobic exercise program that also lasted 10 weeks.

This study had several limitations: (a) the small number of participants in each group impaired the statistical power and the ability to conclude significant effects; (b) due to sampling limitations we were unable to randomize placement of children in each intervention group. Therefore, the ability to generalize to other samples is impaired. However, children in each group were matched as closely as possibly in terms of age, gender and GMFCS levels, and entering locomotor performance did not differ between groups; (c) several participants did not complete the post-test and had to be excluded from the sample. Direct calorimetry with young children with disability is difficult to perform, and some participants were unable to comply for the required periods of time; (d) the lack of a control group that did not train at all may raise the question that maybe the outcomes observed are of physical growth, rather than of training. However, we calculated MCW using the value of VO_2 consumed per Kg body mass. In addition, pre-test to post-test measurements of stature and body mass did not show any significant differences. Therefore, it seems unlikely that the changes observed in MCW and walking speed are merely due to growth.

In summary, based on our findings, both aquatic and land-based training influenced performance. Aquatic training appears to impact somewhat more favorably the metabolic cost during steady state walking, mostly due to the higher speed while walking at steady state. Both aquatic and land-based training appear to have impacted speed in short term walking tasks. Further study of the aquatic training environment is required in order to (a) verify the results obtained in this study by means of a larger sample and multiple baseline design, and (b) explore the mechanisms underlying the changes revealed in our and other aquatic intervention studies.

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