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The Partial Immersion Aquatic Approach Using Adjustable Weight Bearing to Improve Posture and Sitting Balance Adaptation for Children with Severe Cerebral Palsy

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The Partial Immersion Aquatic Approach Using Adjustable Weight Bearing to Improve Posture and Sitting Balance Adaptation for Children with Severe Cerebral Palsy

Cover Page Footnote

The authors acknowledge the Association for the Diseases of Lung and Tuberculosis, Rechovot Branch, Israel, for their support to underwrite part of this research study.

Abstract

The innovative "Partial Immersion" Aquatic Therapy Approach was developed to enhance balance and posture during sitting adaptation for children with severe cerebral palsy who exhibit deficiency in those skills on land. Stable balance during sitting posture is one of the preconditions for hands function in activities of daily living. Aquatic skills learned during aquatic therapy were then transferred to a land environment. Therapy included the use of a treatment chair that enabled adjustable weight bearing in a series of 30 mm steps. A mixed-methods design employing a multiple case study approach (n=5) including quantitative and qualitative methods investigated the effectiveness of the proposed treatment. Cases were tested at pre-and post-treatment times (base-lines 1 and 2) and at a 12-month follow-up point. All participants improved posture and balance adaptations during free sitting on land. Water intervention treatments achieved the highest improved output result as measured per minute of treatment time. Combined water-land treatments achieved less efficient results and the land-only intervention achieved the lowest output results in relation to minute of treatment time. The findings extend our knowledge in relation to theories of natural selection, motor control, motor learning and dynamical systems.

Keywords: aquatic therapy, cerebral palsy, sitting, buoyancy, gravity, weight-bearing, activities of daily living (ADL)

Introduction

Cerebral palsy (CP) is a physical disability that appears in childhood (Rosenbaum, 2003). CP is a general abbreviation that includes a variety of motor disorders. As a result of pre- or peri-natal brain damage, it affects the central nervous system which in turn affects movement and posture and results in dysfunction starting during the early years of infancy and consequently affecting development, functioning, Activities of daily living (ADL), and the typical participation of the child in his/her environment (Rosenbaum et al., 2007; Dimitrijevic et al., 2012).

The rationale behind the partial immersion approach (PIA) (Harrison & Bulstrode, 1987) suggests that most species have adapted to their environment (Romanes, 1895) according to their individual needs. Maladaptation has several impairment consequences for children exhibiting CP behavior in their environment. The first consequences are central nervous system (CNS) impairments which cause both primary and secondary physical impairments. This may affect the performance of a child's gross motor activities and ADL in his/her environment (Morris & Geigle, 2009). The consequences of CNS impairments created developmental delays in optimal postural control and difficulty in a child adapting to the gravitational environment as suggested by Conductive Education (Hari & Akos, 1988) and Neurodevelopmental Therapy (Howle, 2004) that results in difficulty performing ADL, functional activities, and participation in physical activities. The difficulties with postural control in a gravitational environment result in difficulty to sit and/or reach independently during function on a stool on land, as measured by the Gross Motor Function Classification System (GMFCS) of level IV-4 (Palisano et al., 1997) and/or a Gross Motor Function Measure Manual total score between 19% and 34% (Russell et al., 1993). The difficulty in independent sitting and manual functioning represent the most important justification behind the partial immersion approach (PIA) as it deals with the child's functional capability.

Research focused on interventions intending to increase trunk stability on land for persons with CP has attempted to apply a sitting base in different positions of inclination or sloped angles to improve posture with functioning while sitting (Brogren et al., 2001; Carlberg & Hadders-Algra, 2005; Van der Heide et al., 2005). Other studies have advocated the child's sitting with different supports, other stimulations, or customized chairs (Park et al., 2001; DeLuca et al., 2003; Holmes et al., 2003; McDonald & Surtees, 2007; Chen & Yang, 2007).

As noted earlier, Neurodevelopmental Therapy and Conductive Education have suggested adopting an unsupported free independent sitting position (Cotton, 1965; Bobath, 1984) on the flat horizontal base of a stool (Brogren et al., 2001; Stavness, 2006; Hadders-Algra et al., 2007). Accordingly, the Therapeutic Treatment Chair (TTC) is a flat seat base operated in an aquatic therapy (AT) environment which provides significant rehabilitation benefits using the physical properties of water (e.g., unsupported free independent sitting uses the effect of up thrust of buoyancy, facilitating a reduction of the effects of gravity on one's body parts in water) (Harrison & Bulstrode, 1987). These conditions reinforce the opinion that the "aquatic environment, and particularly buoyancy, enables (CP) children to be more active…. These opportunities are limited on land because of gravitational constraints" (Getz et al., 2007, p. 226). The sum of all previously-described consequences suggests that CP may be accompanied by behavioral problems, altered perception, deficient intellectual abilities, or perceived lower intelligence so that the child appears to be both physically and mentally disordered (Abercrombie, 1968; Scherzer & Tscharnuter, 1990; Rosenbaum et al., 2007).

This current research study investigated the effectiveness of PIA using a TTC innovation technique; thus, the research question asked by this study was whether it was possible to regulate and control the percentage of weight bearing on the child using the TTC to create a gradual progression from an unloaded seated position toward a loaded position in the water that would permit the transfer of acquired sitting skills in water to free sitting on land.

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To answer this rather complicated yet specific question, various elements needed to be considered. First, in order to improve a child’s ADL skills, free sitting ability must be developed so that the child with CP “will have sufficient balance in sitting [on land] to use his hands freely” (Bobath & Finnie, 1958, p. 3). This should allow the child to adapt to and function better in his/her environment. Second, as mentioned previously improved function and ADL may reduce the appearance of mental disorder for the child with CP.

A small amount of research has focused on AT environments that may reduce conditions of a gravity environment (Miyoshi et al., 2004) by regulating and controlling the percentage of weight bearing using the mechanical innovative of a TTC instrument. Although several studies involving normally-abled people have investigated the technique of PIA by roughly regulating the percentage of weight bearing option (Harrison & Bulstrode, 1987; Harrison et al., 1992), the interventions didn't use fine gradations in lifting the participant upwards from the water.

Additional options in AT using PIA to achieve trunk stability to improve upper extremity functioning skills by regulating and controlling the percentage of weight bearing include sitting on a board practicing the balance reaction and increasing trunk strength by maintaining one’s position while a therapist tilts the board (Fragala-Pinkham et al., 2009). Alternatively, having the child sit on a pool noodle to balance while the therapist helps provide resistance or assistance may allow the child to practice seated balancing (Fragala-Pinkham et al., 2014). The child also could sit on the therapist's leg while using a disengagement - sequence of reduction support strategy to improve the balance skill through the Halliwick Approach (Vargas, 2004), Watsu Approach (Dull & Schoedinger, 2004), or Pediatric Aquatics Therapy (Petersen, 2004). One might also proceed as Morris (2004) did when he conducted similar activities in water with a Task Type Training Approach and Bad Ragaz Ring Method, using a combination of buoyant supporting objects to improve buoyancy and then gradually reducing buoyancy over time. One research study involving persons with CP in AT followed the strategy of PIA with an uncontrolled “progression including moving to more shallow portions of the pool” (Maynard, 2004, p. 24). The above example is used by the present AT rehabilitation literature (Fragala-Pinkham et al., 2009). None of the mentioned study approaches regulated or controlled the percentage of weight bearing or gradually controlled the child's adaptation process as the main element of the current research. The present study aimed to address gaps in knowledge by adding a specially developed TTC to improve the unloading toward loading transfer strategy. Thus, a gradually adapted environment was formed at each lifting stage due to an altered buoyancy-gravity relationship applied for the child with CP. The study therefore aimed to investigate whether reduction of the impact of gravity conditions (Miyoshi et al., 2004) by regulating and controlling the percentage of weight bearing in an AT environment could facilitate sitting adaptation on land for children with severe CP disabilities (Becker, 2004).

Method

Participants

The present study's population consisted of 238 children with CP in the city municipality (Ministry of Education, 24th March 2005). A convenience sample designated 11 participants, which was 4.6% of a diverse CP population of 238 who were selected according to the available research resources. Six initial participants were excluded from the research.

Five participants (males=4, females=1) aged 10-15.4 years (mean = 11.7 years old, SD = 2.1) (Table 1) met the research criteria procedures according to the following inclusion criteria which were (1) diagnosis of CP by a neurologist; (2) age within the identified range; (3) topographical classification of bilateral CP; (4) physiological classification of ״*spastic CP subtypes*” (Cans et al., 2007); (5) GMFCS level IV-4 (Palisano et al., 1997); (6) Gross Motor Function Measure Manual total score between 19% and 34% without socks, shoes, orthoses, or aids (Russell et al., 1993); (7) capacity to comprehend instructions; (8) no surgery or casting during the last 6 months or injections for spasticity; (9) no fixed deformities of shoulders, hips, or lumbar joints; and (10) inability to reach out while sitting on a stool independently on land. Table 1 presents participants’ anthropometric measurements and characteristics. Participants were chosen according to the selection criteria because of their similar characteristics.

Table 1
Participants anthropometric measurements and characteristics

Case No	Free Sitting Time (min. sec)	Total Distance of Immersion (mm)	Age (year. month)	Weight (kg)	Height (mm)	Arm Span (mm)	GMFCS Level (IV-4)	GMFM Score (%)
Case 1 (P)	0.40	300	15.4	41.12	1315	1280	IV	00.00
Case 2 (r)	10.30	267	11.1	17.30	1225	1240	IV	34.40
Case 2 (c)	10.01	250	11.0	19.70	1277	1034	IV	24.70
Case 3	10.00	297	10.0	20.13	1220	1275	IV	28.84
Case 4	0.52	312	11.11	40.20	1266	1101	IV	19.24

Key: P: Pilot study; r: Research Participant; c: Control Participant; GMFCS: Gross Motor Function Classification System; IV: Palisano et al. (1997); GMFM: Gross Motor Function Measure.

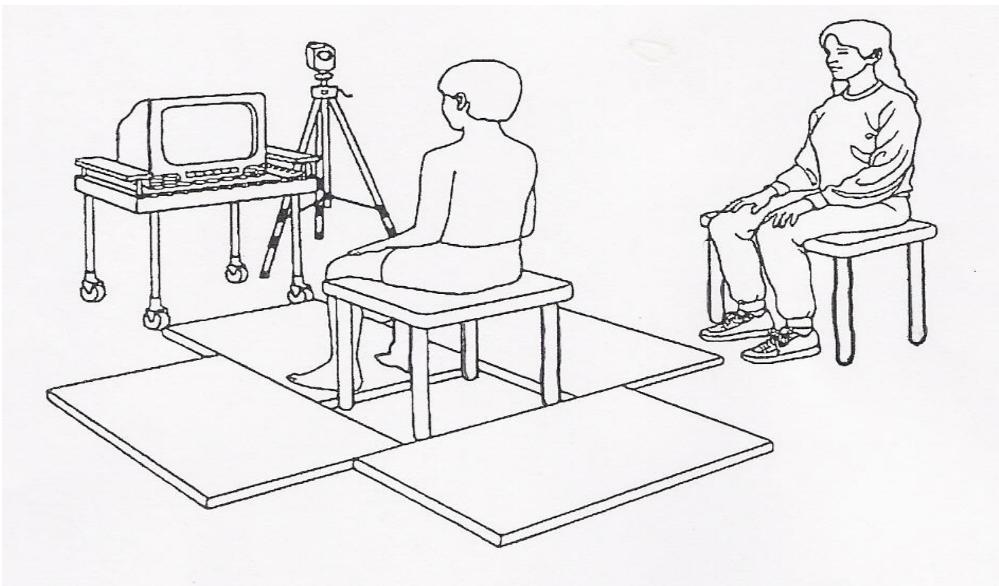
Research Instruments

The Universal Goniometer (Clarkson, 2000) ('Baseline TM' Chattanooga Group Inc.) was used to obtain joint range of motion (ROM) on a scale of degrees and has been shown to be reliable (Boone et al., 1978; Clarkson, 2000). Prior to taking each set of measurements, the goniometer was carefully calibrated against a Metzger No. 02169 digital angle analyser with known angles of 50^o - 60^o -70^o.

The study measured two aspects of joint range of motion. Both passive ROM while in a supine position and active ROM in a sitting position on the test chair were measured. When the active ROM of trunk flexion at the hip joint was measured during sitting, a greater ROM indicated better dynamic sitting balance (Reid, 1997). The calculated results were based on a mean of three trials (Clarkson, 2000). The differences in the goniometric measurements (in degrees) between pre- and post-intervention tests were used as the ROM data. The goniometer's intra-rater reliability coefficient was 0.94 to 0.98.

The Sitting Assessment for Children with Neuromotor Dysfunction (SACND) (Reid, 1997) also was used. Four sitting behaviors were assessed by videotaping the child's static sitting. Each behavior was rated on a 4-point scale. During assessment, the participant sat on the test stool and watched a movie. A TV monitor and videorecorder were placed in front of the child at the child's eye level. A video camera was placed 5 to 6 feet in front of the stool and approximately 45 degrees from midline to one side recording the child's posture angle during sitting performance for 5 consecutive minutes (see Figure 1).

Figure 1
Static Sitting Assessment Situation



Note: Taken from Reid, 1997, p. 10.

The calculated results were based on the differences in the judged SACND evaluation of sitting posture between pre- and post-intervention tests. Cronbach's alphas calculated the reliability of the SACND behaviors as 0.81

to 0.87 using three raters. Discriminant analysis assessed a construct validity of SACND. The total Z score was 2.90 with p = 0.003 (Reid, 1997).

Other tools used were the Gross Motor Function Measure Manual (Russell et al., 1993) and the GMFCS (Palisano et al., 1997). These are standardized insturments that classify the gross motor function of children with CP. The tools were used only in the pre-intervention test to identify whether the participants met the inclusion criteria. The reliability and validity of both tools are well documented in the literature (Nordmark et al., 1997; Ko et al., 2011).

The Non-Directive Focused Interview (NDFI) (Merton & Kendall, 1946) was used along with the baselines using identical procedures, questions, format order, and respondents. The intention was to verify the child's sitting balance adaptation status on land as expressed in movement and posture. NDFIs took place with the child, the child's parents, physical therapists, and/or conductor, conductor assistant, teacher, teacher's assistant, and/or caregiver. NDFIs were recorded before the intervention (Table 2, A1), after water and land interventions (A3), and after one-year post-intervention (A4).

Procedures

A mixed-methods design using quantitative core and supplementary qualitative data (Morse & Niehaus, 2009) was chosen using multiple case study replication logic. Triangulation between methods and between times (Denzin, 1970; Yin, 2003) was used to increase the rigor of the collected data (Nachmias & Nachmias, 1996). These strategies enabled the researcher to reduce errors and biases and to enhance the validity, reliability, and generalization of the data (Yin, 2003; Shkedi, 2005).

Quantitative and qualitative data were analyzed separately, and then both data sets were integrated (Morse & Niehaus, 2009). The primary core quantitative data analysis was based on the calculation of differences between pre-/post-test intervention, analyzing data from goniometry and SACND tools at different base lines. The qualitative analysis related to data from the NDFI tool (see Appendix) underwent open coding and was broken down for analysis within each case on data collected at the A1, A3, and A4 base lines and between the cases while searching for differences and similarities (Table 2). The selected data were then grouped and developed into categories. Table 2 below shows the type of tools (quantiative core and supplementary qualitative tools) used at each different stage of data collection for each case according to A1 /B/ A2 /C/ A3 /D/ A4 base lines.

Table 2
Mixed-methods design showing details of data collection according to A1/B/A2/C/A3/D/A4 base lines, quantitative core and supplementary qualitative tools

A1 Baseline	B Inter	A2 Baseline	C Inter	A3 Baseline	D Inter	A4 Baseline
Pre-Intervention	PIA Water using PIA with TTC, establish water inter.	Post-inter. test 1- calculated: Water Inter. (A2 minus A1)	PIA Water and land Inter. using PIA with TTC	Post-inter. test 2- calculated : Water & Land Inter. (A3 minus A1). Calculated: Post- inter. test 3 - Land Inter. (A3 minus A2).	One year period: testing stability of sitting and balance findings over time.	One year post-inter.
Core-Quantitative Tools:		Core Quantitative Tools:		Core Quantitative Tools:		Emergent Design Qualitative
Goniometry SACND GMFM GMFCS		Goniometry SACND		Goniometry SACND		
Additional Qualitative Tool: NDFI				Additional Qualitative Tool: NDFI		Tool: NDFI

Key: Inter: Intervention; GMFCS: Gross Motor Function Classification System; SACND: Sitting Assessment for Children with Neuromotor Dysfunction; GMFM: Gross Motor Function Measure; NDFI: Non-Directive Focused Interview

Interventions

The interventions were a composed set of structured exercises. The introduction of the participant's sitting skills on the TTC was on land with assistance. The mechanical leg support was adjusted to individual participant's leg dimensions to maintain the child's legs posture as close as possible to a fixed 90^o angle at the hip, knee, and ankle joints (Reid, 1997). This individual fixed-leg sitting position was maintained during all treatments in water and on land environments in order to equalize the conditions under which the data were collected between environments and during evaluations.

The TTC was assembled on a horizontal level on the pool bottom of an average pool water temperature of 33.6^{o}C. Next came the adjustment of the TTC heights to the individual participant's shoulder level water height in the sitting position. According to Becker (2004), the "law of buoyancy… Archimedes principle… may be of great therapeutic utility" (pp. 23-24) to support the participant while sitting in the water. The AT teacher was in the water in front of the participant, and as needed, s/he assisted the participant during pool treatments from the front by stabilizing his or her two hips to the chair base with one hand. The other hand guided the participant's nose during trunk flexion while the head lead the movement that affected body movement.

All participants were raised (i.e., load increased) from the water once a week by 30 millimeters after sitting and balance adaptation improved during this phase of water level. At the end of water treatment sessions for all participants, the water line was levelled with the hip joint, and the participant was transferred to the same sitting position and conditions as on land. Then the land treatments were continued with the entire body subject to full-gravity conditions. Rhythmical intention (Hari & Akos, 1988) developed by Professor Peto is defined as the mental preparation of a symbol display system in the cortex system toward intentional behaviour (Leon, 1987). It is a form of facilitation with two main purposes: to help make motion voluntary, active, and according to a rhythm. Rhythmical intention was the basis for all the treatment exercises. It was used equally in both environments, water and land, for all participants.

Strength Posture of the Trunk (SPT) was provided for all participants (including pilot) and in accordance with the definition of balance by Reid (1997, p. 4) and with "Trunk Control Assessment" of Preston (2001, pp. 376-378). "I flex my trunk forward, one, two, three, four, five" and "I extend my trunk back", etc. (Leon, 1987, p. 18; Hari & Akos, 1988, p. 209). SPT started from the base sitting position (see Figure 1) and always returned to it.

In the first pilot case intervention a total of 16 water sessions of 45 min. each were provided 5 times a week. In the second case, two participants carefully matched for close similarity were found. The research (r) participant received PIA of SPT equally in water and land environments in water (20 sessions of 60 min each, 4 times a week) followed by SPT land treatment (82 sessions of 10 min each, 7 times a week) with a total of 102 water and land treatments. While the control (c) participant only received SPT land interventions, identical to those of r participant, with a total of 82 land treatments only. In the third case, the participant underwent SPT alternating every other treatment day with ADL Skills Function (ADLSF). ADLSF related to skills training involving hand-to-head coordination, all beginning from the base sitting position: holding a tool (e.g., toothbrush), bringing it to the target (i.e., the mouth), bringing it back from the target, and returning to the base sitting position.

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The third case underwent water treatment (24 sessions of 60 min each, 4 times a week) and SPT alternating with ADLSF on land treatment (20 sessions of 60 min each, 4 times a week) with a total of 44 water and land treatments. In the fourth case, the participant underwent SPT alternating with ADLSF water treatment (16 sessions of 60 min each, 4 times a week) and SPT alternating with ADLSF land treatment (27 sessions of 60 min each 4 times a week) with a total of 43 water and land treatments.

The research and evaluations were conducted in the pool at Tamar special school facilities for children with neuromotor impairments. Procedures and conditions were standardized in a specific order across all testing sessions maintaining the same uniform order and types of treatments for the selected cases. The same evaluator was consistently used for all participants and was blinded to the calculation of results and the intervention sessions of the study. An agreement and a letter of consent were signed by all participants before the study took place. The study practice procedures, protocol, and guidelines were mandated and approved by the Ministry of Education and lasted 5 years.

Results

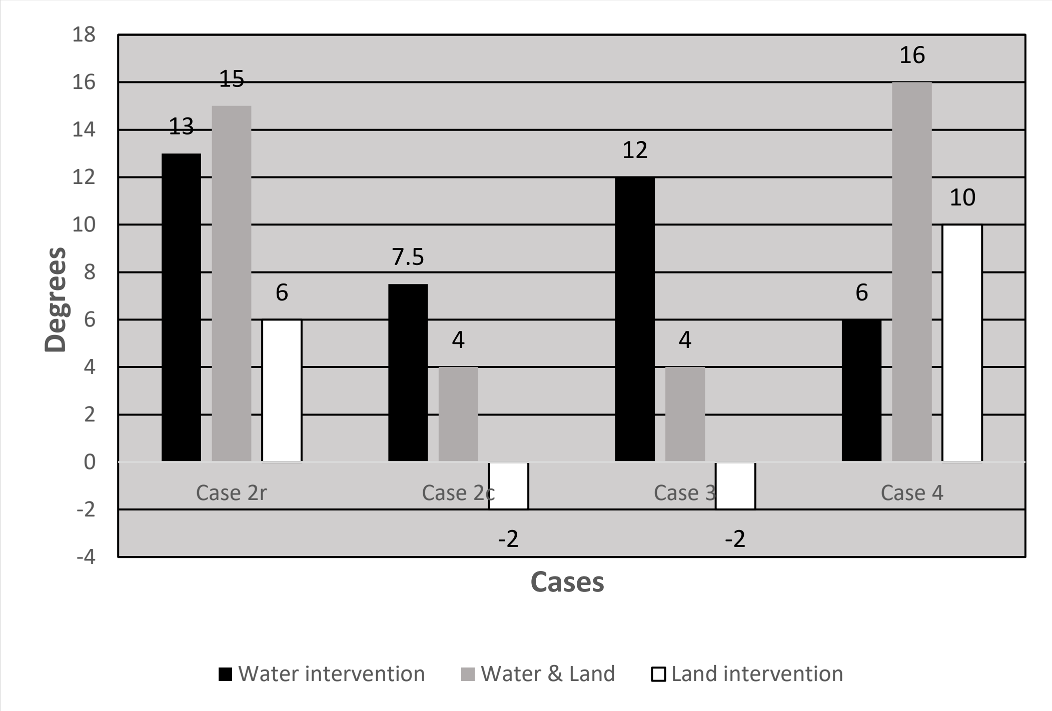
Figure 2 shows the difference in the goniometric measurements (degrees) of hip flexion at the different pre- and post-intervention tests, each participant representing different numbers of treatments in different treatment environments.

The four replicated cases that were exposed to the PIA water intevention (black) demonstrated an increase in ROM in the flexion of both hips and improved the quality of at-rest free sitting for all participants (Reid, 1997). The PIA of water and land with the longest intervention time (in grey) showed a total degrees of improved ROM in the flexion of both hips with increased sitting quality and balance which was higher than water alone or land interventions alone. Cases 2c and 3 showed a decrease in total degrees of ROM in the flexion of both hips and yielded reduced quality and balance of free sitting in comparison with water intervention. Land intervention (white) had the shortest treatment time of PIA and showed less beneficial ROM in the flexion of both hips and yielded reduced quality and balance of free sitting in comparison with the other two interventions (i.e., water and water and land interventions). Case 2 c. and Case 3 exhibited negative land results.

Table 3 presents data relating to the different water and land environments using the input of participants' treatment time in minutes and the output of the amount of ROM improvement in degrees.Table 3 indicates that the result for the PIA water-only intervention (3600 min of improvement and 38.5 total degrees ROM across all four participants) revealed improved degrees per minute of treatment time (IDPMTT) that equaled 0.010 degree per minute improvement. These results of water intervention were more effective in

Figure 2

Cases differences in goniometric measurements (degrees ROM) of hip flexion at the different pre- and post-intervention tests, each participant representing different amounts of treatments in different treatment environments



Key: r = Research; c = Control; ***Total degrees improved: Water-38.5; Water & Land-39; Land-12.

Table 3

Effectiveness of intervention in different environments: Input - Participants' Treatment Time (minutes) Output - Amount of Improvement (in degrees ROM)

Environment	Case 2 r.		Case 2 c.		Case 3		Case 4		Total		
	Min	D	Min	D	Min	D	Min	D	Min	D	IDPMTT/ D
Water	1200	13	0	7.5	1440	12	960	6	3600	38.5	0.010
Water + Land	2020	15	820	4	2640	4	2580	16	8060	39	0.004
Land	820	6	820	-2	1200	-2	1620	10	3002	12	0.003
Case Totals	4040	34	1640	9.5	5280	14	5160	32	14662	89.5	
Case Mean	1346	11.3	546	3.1	1760	4.6	1720	10.6			

Key: Min = Minutes; D = Degrees; IDPMTT=Improved Degrees Per Minute of Treatment Time

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proportion to the amount of treatment, compared to the total results from water and land intervention (8060 min per improvement of 39 degrees, IDPMTT = 0.004 degree). Land-only intervention (3002 min per improvement of total 12 degrees) resulted in IDPMTT of 0.003 degree.

Table 3 indicates that the mean result of each individual case improved as a result of the PIA treatments in the three environments: water, water and land, and land. Cases 2 r and 4 improved more in degrees than cases 2 c and 3.

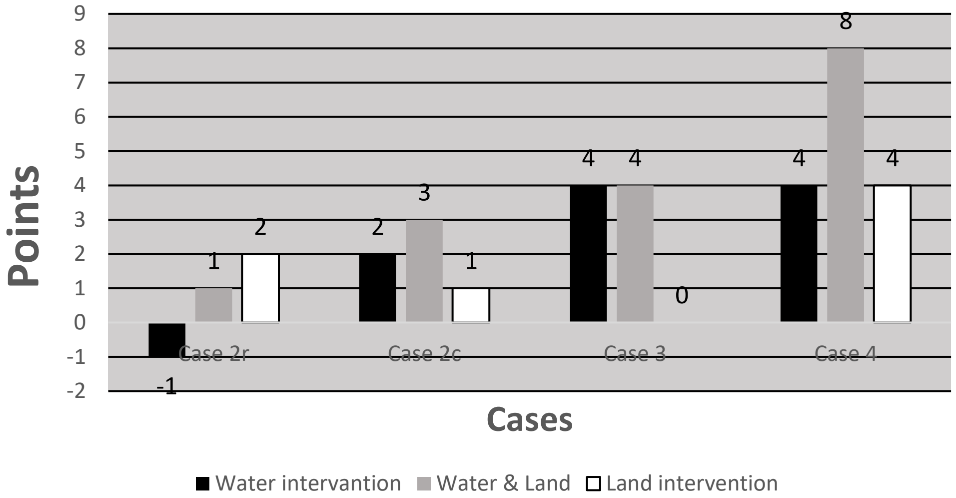
The research objective was informed on the basis of knowledge gained in the pilot study. "The pilot case is (useful in many ways)…possibly even providing some conceptual clarification for the research design as well" (Yin, 2003, p.79), and for "methodological issues" (p.80). Thus, the pilot study formed a firm basis on which to develop and construct the subsequent research interventions used in the study. The time between the pre-and post-treatment of the pilot was 19 days only. Reduction of the depth of the body immersion was 60 and 80 mm, with two chair lifts per a week. Water-only intervention (720 min per improvement of 9 degrees) revealed IDPMTT of 0.012 degree.

Figure 3 shows evaluations of the differences in sitting posture measured according to the judged SACND rest module evaluation (in points) and compared between pre- and post-intervention tests, each participant representing different amounts of treatments in different treatment environments.

The PIA water intervention (black) yielded an improved sitting quality and balance during free sitting in all participants except for Case 2 r, which yielded negative results. The PIA water and land intervention (gray) yielded a a total of improved sitting quality and balance higher than the water only and land only interventions, but with more treatment time. Land only intervention (white) yielded less beneficial quality and balance of free sitting in comparison with the other two interventions (i.e., water only and water and land intervention). The difference in levels of effectiveness for the different treatment environments is illustrated in Table 4 below.

Figure 3

Differences in sitting posture measured according to judged SACND rest module evaluation (in points) between pre- and post-intervention tests, each participant representing different amounts of treatments in different treatment environments



Key: r: Research; c: Control.
*Total points improved: Water-9; Water & Land-16; Land-7.

Table 4

Effectiveness of intervention in different environments measured by SACND rest module: Input - participants' treatment time (minutes) Output - amount of improvement (points)

Environment	Case 2 r.		Case 2 c.		Case 3		Case 4		Total		
	Min	P	Min	P	Min	P	Min	P	Min	P	IPPMTT
Water	1200	-1	0	2	1440	4	960	4	3600	9	0.0025
Water + Land	2020	1	820	3	2640	4	2580	8	8060	16	0.0019
Land	820	2	820	1	1200	0	1620	4	4460	7	0.0015
Case Total	4040	2	1640	6	5280	8	5160	16	16120	32	
Case Mean	1346	0.6	546	2	1760	2.6	1720	5.3	5373.3	10.6	

Key: Min: Minutes; P: Points; IPPMTT=Improved Points Per Minute of Treatment Time.

Table 4 assessed the effectiveness of intervention in different environments measured by SACND rest module; the input – participants' treatment time (in minutes) and the output – amount of improvement (in points). The total time mean (Table 4) for PIA water intervention (3600 minutes per improvement of 9 total points). Improved points per minute of treatment time is (0.0025 points). This indicated that this treatment produced a higher points proportion to the amount of treatment, if compared to results of PIA water and land intervention (8060 minutes, improvement of 16 total points or improved points per minute of treatment time of 0.0019 points), and the land-only intervention (4460 minutes and improvement of 7 total points or improved points per minute of treatment time of 0.0015 points). Table 4 indicates that the mean result of each case individualy improved by the PIA treatments in the three environments: water only, water and land and land only. Case 4 improved the most, after case 3 and then cases 2 c and 2 r in the end, with lowest mean results.

In addition to the measured results, qualitative descriptions were obtained from the participant and participant's staff regarding the child’s sitting before and after the interventions, describing the changing skills of CP participants during free sitting on land. In Case 2 r, the boy and his mother described how scared he was before the treatment. When he had sat unaided on a stool previously he admitted that he sometimes had fallen in such a situation. After the treatment during an interview with the teacher, it was revealed that "it is evident that Case 2 r is able to sit continuously with an upright back for a few minutes.” Case 2 c, before the treatment, faced a threat to his safety. As the physiotherapist said, "he falls sideways, forwards, and also backwards. It was not safe, and we did not manage to progress.” After the treatment the physiotherapist, the assistant teacher, and the teacher described an improvement, saying sitting time had increased to half an hour and more. Finally, before the treatment, Case 4, together with her parents, the physiotherapist, and the conductor, described that she could sit freely for a number of seconds up to one minute. After the treatment, the mother and the conductor described a significant improvement in sitting time, from 50 seconds up to "almost one hour.”

One Year Follow-up Evaluation

During the one year post intervention evaluations (Table 2, A4) the parents of the participants and participants were interviewed regarding the quality of the static sitting and the trunk posture of the participants’ behavior. All interviews were typed and opened according to different topics of categories. The subsequent data describe static sitting skill and erect posture during ADL of the participants. The parents of all participants described improvements of sitting skills of movement and posture (e.g., pilot mother related to his improvement in skills: "His sitting during the period improved very, very, very much.”) Case 3s mother described postural improvements of her child's back one year after the treatment ended: "He sits very straight…his back is straight.”

The mother in Case 4 emphasized the development of ADL functional activities: "Yes, there is improvement… she can even eat some things by herself; we do not even put it [the handkerchief] in her hand. I put it on the table, she grasps it, and somehow she manages to eat alone; she can eat alone." Parents' desire and recommendations to renew and continue with the therapeutic intervention that ended a year earlier. The opinion of all research participants' parents (one year after treatment) and the opinion of the parents of the pilot test participant (two years and 8 months after the pilot treatment) were that they had been satisfied with the treatment and would like to continue to receive these treatments (e.g., the pilot test participant himself acknowledged the benefits of the treatment: "I understood that this therapy, this is what helped.") Case 3's mother suggested that it was a good time to start a second treatment. "This was good for Case 3… So you are invited to do the second stage in the research after the summer." Finally, Case 4's mother pointed out the positive results of the treatment: "If N… could continue with the therapy in the context of the school and privately, I think that there would be many parents who would continue with this therapy, because we saw results; it was not simply something up in the air."

During the research and during the one year follow-up evaluation, descriptions were obtained that may suggest that parents/caregivers of participants saw the progression and improved performance in posture of static sitting skills the year before and wanted to repeat it again. The pilot participant's mother used the Researcher's Pilot Study photographs (taken during post evaluation) to identify the most appropriate chair as well as posture for her child: "This means that we sat him on chairs like we saw in pictures [two years and 8 months after the treatments] and we used this [understanding] at home as well." Case 2r's father explained how the family had changed their behaviours on Saturdays and the family's new procedures for improving Case 2r's sitting posture. "So I think that it also made us aware of the importance of making frequent remarks. And now we decided to go out on Saturdays, to take him out, and we do this on a permanent basis, and as soon as he bends over, we stop until he straightens up, and this goes on the whole way. I really attribute this to you-N… [the researcher]." Finally, Case 4's mother described and gave an example of how the participant's parents had started to demand more from their child as well as correcting their child's posture: "We saw that she was able [to sit alone] therefore we could ask her to do more things [that can be done] with upright sitting, so in movement or in another situation of the therapy she can be asked to sit more correctly, and then she also helped [us]."

Both Figures 2 and 3 and Tables 3 and 4 exhibit a total of 14 positive quantitative evaluations, including the pilot case. In Tables 3 and 4 each individual case improved their total mean sitting time across each of the three intervention environments: water only, water and land, and land only were positive. The 14 positive (and only three negative evaluation results) can be seen in Figures 2 and 3. The qualitative method helped to describe the positive phenomena of improved posture of static sitting skills including at the one year post intervention. It suggested that a positive improvement of participants' static sitting took place in present investigation.

Discussion

In the present study the PIA in the water only intervention environment was the most efficient intervention revealed by the highest degrees (or points) per minute of treatment time evaluated by the goniometer, SACND rest module tools, and the NDFI tool. The participants received the longest time of PIA in the water and land intervention and produced the superior results; the land-only intervention with the shortest time not surprisingly produced the weakest results and appeared less beneficial for developing free sitting and balance on land. Cases 2c and 3 (Fig. 2) showed a decrease in the ROM under water & land and land only interventions when compared to the water only intervention. Also, some negative results appeared for Case 2c and Case 3 after the land-only intervention (Figure 2). The decrease and negative results seemed to indicate that the heated water environment and properties of water variables in some way were beneficial to increasing the hip ROM than the conditions of the water & land and land-only environment intervention. AT treatment for children with CP with the recommended water temperature in the range of 33.3-35^{o}C (Dull & Schoedinger, 2004) might have also facilitated tissue elongation, relaxation, and therapeutic learning. Several studies have supported the beneficial effects of warmer water and hot packs to increase joint ROM among the average non-disabled population (Campbell, 1955; Grobaker & Stull, 1975; Alter, 1996). Another explanation includes the benefits of aquatic environment with the physical properties of water that includes buoyancy, viscosity, density, and hydrostatic pressure that provide significant rehabilitation benefits to increase joints' ROM in a water environment (Becker, 2004; Irion, 2009). Negative results appeared for Case 2r with the water only intervention (see Figure 3). These negative results seemed to indicate that during the SACND rest pre-post evaluation, the result did not match the improvement in sitting as described in the qualitative data by the child's teacher. One possibility might have been measurement error associated with the SACND judged observation evaluation. Another possibility may have been that Case 2 r did not perform as well as other cases during SACND rest evaluation time. The two rather different instruments (Tables 3 - Goniometry and 4 - SACND) evaluated static sitting in the present research. The PIA in water was shown to be the most efficient intervention environment in terms of improved degrees and points per minute of treatment time (input) and improved sitting by increased degrees ROM and points (output). In the improvement of ROM field, similar or even better results of improved degrees per minute of treatment time were obtained from the pilot study in the same PIA technique but with shorter, more intense and aggressive treatment of regulate and control the percentage of weight bearing (RCPWB). This corresponded with the findings of previous published work relating to the achievement of increased ROM in heated water intervention after AT treatment for people with CP (Shelef, 1998; Fragala-Pinkham et al., 2009). These studies might help to explain the increased ROM of hip flexion of children with CP after PIA heated water intervention which consequently produced improved sitting and balance (Reid, 1997).

The triangulation of quantitative data from the goniometry and SACND tests with qualitative data from the NDFI to the category of "improved sitting for a relatively long time" demonstrated that the PIA water treatment produced an improvement in at-rest free sitting and balance (Reid, 1997). These data were compatible with similar RCPWB conditions in previous studies (Harrison et al., 1992; Fowler, 1997; Miyoshi et al., 2004) in which treating the able-bodied population in standing/walking improved gross-motor functioning. This finding was also compatible with the outcome of two rather identical AT studies involving children with CP using similar procedures of gradual progression reducing depth of immersion (Irion, 2009) yet with no specific quantitative control of measurement recommendations. The aim of the two studies was to evaluate the effectiveness of the aquatic exercise program on function and walking abilities in children with CP. Both studies used a pool with an adjustable floor for the purpose of varying the water depth. Fragala-Pinkham et al. (2009) used four participants in a case series with just two males diagnosed with CP both functioning at GMFCS level -I. Case 2 involved a 7 year, 10 month old child with spastic diplegia. Case 3 was a child of 10 years, 11 months of age with right hemiplegia. The RCPWB intervention for Case 2 was balance activities in water at chest height level. After progressions, the balance activities were performed at waist-level water to knee-deep level. Case 3 was gait training using the pool floor and treadmill with the water at chest height level. After progressions, the water depth was decreased to waist level. All of these findings of RCPWB using unloading toward loading conditions in a very crude manner (Maynard, 2004) resembled the present AT rehabilitation approaches (Morris, 2004). Those approaches neglected the sensitive control transition to the land environment as used in the present research by the TTC which involved the needs of children who functioned at GMFCS levels IV-V. Other treatments of PIA investigation (Harrison & Bulstrode, 1987; Harrison et al., 1992; Maynard, 2004; Miyoshi et al., 2004) employed activities involving gross motor tasks of standing, walking, and running. The current study improved the task of independent sitting to accommodate children who functioned at the GMFCS levels IV-4. Other treatments by the previous researchers failed to emphasize the need for successful RCPWB to use the reduction of buoyancy by 30 mm max steps. The current study proposed that gradual steps in RCPWB would facilitate the adaptation process. The current study of PIA using the special TTC tool provided a technique that had not been employed in previous studies and therefore we felt we contributed to the expansion of knowledge in this field.

PIA in a water and land intervention produced superior results due to using the largest and longest number of treatment sessions as illustrated by the quantitative data in Figures 2 and 3 triangulated with the qualitative data from the NDFI tool. The explanation for this positive finding could have been due to the greater time in practice or that the water and land practice transferred achievements gained in water using PIA and TTC to improved RCPWB in the land environment. The answer to those possible explanations in quantitative method will require an additional study where the amount of practice should be held constant.

Using the PIA protocols in both environments appeared to provide assisting environments for treatment in which the therapist could control the gravity load (Harrison et al., 1992) in water while facilitating the child's practical skills experience on land (Howle, 2004). It provided an opportunity to master skills using a gradual progression that may have allowed transfer of skill achievements in water to land environment conditions (Morris, 2004; Fragala-Pinkham et al., 2009). This gradual progressive strategy was also mentioned in the approaches of dynamical systems theory (Thelen, 1995), conductive education (Brown, 1997) and neurodevelopmental therapy (Howle, 2004). The gradual progessive strategy proved to be the most beneficial learning context by improving quality and balance of at-rest free sitting. The consequent positive findings seem to have been unique to this research.

Land environment treatment in present study produced the results with the least overall improvement. Data for land-only treatment (white column-Figures 2 and 3, and total score in Tables 3 and 4) indicated less improvement in the quality of at-rest free sitting and balance compared to the improvement achieved by similar treatments in water and water and land. One explanation for the land results was that is was the intervention with the least amount of treatment time. Motor control and learning theories (Schmidt, 1992) developed on the basis of optimal gravity conditions suggested that land environment intervention may have an inferior effect to water intervention, reflecting the influence of the extrinsic environment with full gravity conditions on the participants.

Enhancing the PIA with the special TTC enabled the use of RCPWB by gradually decreasing buoyancy in steps of 30 mm and gradually increasing gravity conditions. Thus, the therapist was able to increase the control and regulation of the environment in line with the process of intrinsic and extrinsic feedback (closed loop) (Howle, 2004; Getz et al., 2007). The children with CP benefitted from the environment of PIA with the TTC in three ways. First, the participants in the water "had time to react" (Lambeck & Gamper, 2009, p. 46) compared to land since the density and viscosity of the water produced increased resistance to movement which allowed more time for receiving and processing feedback or anticipatory adjustments (Getz et al., 2007). The other two factors included the therapist's control with regulation of feedback using rhythmical intention, strength posture of the trunk (SPT), and activities of daily living, skills function (ADLSF) as well as the RCPWB facilitated by the TTC which all enhanced "feed-forward" feedback and consequently enhanced motor control of sitting (Howle, 2004). It is another way of saying that there was greater "closed loop" control which provided a more effective open loop improvement by the PIA treatment context than on land, where this feedback process was not facilitated.

Limitations and Strengths

The study findings were subject to a number of potential limitations which may infer either weaknesses or strengths. First, we conducted the research with a very limited sample size which did not allow us to draw any statistical generalizations from the findings. Due to the small sample size, we approached "less desirable generalization" (Yin, 2011 p. 226) in participant's improved sitting behaviour in the manner of a multiple case study replication. Yin (2011) claims that results from one study may be sufficiently replicated / generalized to similar situations in another study. This second way of generalization is referred to as external validity. It is believed that multiple-case studies greatly resemble each other and the results of improved sitting are similar in each case. "The development of consistent findings, over multiple cases and even multiple studies, can then be considered a very robust finding…The more replications, the more robust your findings will be" (Yin, 1993, p. 34).

Second, there was a difference in treatments between the pilot, Cases 2r and 2c, which received SPT, and Cases 3 and 4, which had SPT altered with ADLSF on the other day. The benefits of adding ADLSF appeared to be consistent with the specificity training principle (Schmidt & Wrisberg, 2004) for enhanced ADL in water and transfer progression to benefit land activities. Due to the applied nature of this study, these general diverse treatments were carried out to construct the best possible treatment and adapt the treatment to each individual (GMFCS level IV-4) skills, needs, and development. "No two cerebral palsy children are alike and therefore each cerebral palsy child needs different treatment and different exercises" (Bobath, 1974, p. 35). The disadvantage was the interference with the consistency of intervention and the statistical generalizations from the findings.

Third, the intervention time was not controlled equally across the four participants. As a result each served as their own unique and separate case which specifically resulted in a very limited ability to interpret the results simply and clearly. Each separate unique case suggested an improvement in ROM degrees and sitting points during free sitting. To confirm sitting enhancement, the research study produced a total of 44 NDFI (Shelef, 2010) with which these interviews' descriptive data findings helped to reinforce the validity of the study (Stake, 1995) and verified balance and function control during free sitting on land after PIA intervention for children with CP.

Fourth, the limitations issue of bias involved children with severe CP (GMFCS level IV-4) and their staff in the research while applying NDFI. It is suggested to reduce the interviewee's "social desirability bias" (Mason, 1996, p. 40) or "interview bias" (Yin, 2003), the researcher should adopt a structured interview guide with a standardized order of questions, asked in a uniform manner to stimulate responses that would produce more reliable data (Mason, 1996; Cohen et al., 2000; Morse & Niehaus, 2009).

Conclusions

We feel this study made a contribution to the field of rehabilitation since the mechanical innovation of the TTC may form an innovative rehabilitation environment at each lift stage by applying an altered new buoyancy-gravity relation to the child with CP during sitting from the unloading toward loading procedure. The application of this strategy in the field follows a logical notion supported by theory that gradual, progressive changes are particularly effective in rehabilitation. In the case of children with cerebral palsy, the level of the child's motor behavior depends on their capability to adapt to an appropriately challenging environment during neuropathology recovery (Howle, 2004; Rosenbaum et al., 2007; Van Eck et al., 2009). In other words, "the extent of physical disability cannot be determined solely by intrinsic neural and body factors, but takes into account the effects of the environmental context (extrinsic variables) on the disabling condition" (Howle, 2004, p. 85).

The data collected through the two research methods (Shelef, 2010) used in this study (i.e., quantitative and qualitative measures) demonstrated a strong advantage in using the application of PIA rehabilitation treatment. The innovative TTC facilitated regulate and control the percentage of weight bearing in very gradual steps of 30 mm max. This gravity loading progressed from buoyancy-unloading to free sitting under full gravity conditions-loading. This PIA technique enhanced individual child's sitting adaptation skills, and thus constituted one of the innovations of this research.

According to the mathematical interpretations of the quantitative findings, the AT water only intervention environment was the most efficient technique for improving the child's sitting and balance. While a combination of water and land intervention produced a superior outcome for sitting and balance as a result of the longest amount of treatment time. Treatment in a land only environment demonstrated the weakest results although it had the shortest treatment time of the three interventions.

The innovative PIA with TTC demonstrated the value of the gradual progressive strategy to manipulate the child's independent sitting from unloading toward loading, a concept that needs to be further explored and applied in the future. This strategy of developing gradual changes in the therapeutic aquatic environment appeared to help regulate and control feedback, enable anticipatory adjustments, and may improve feed-forward and sitting behaviour performance. It is possible that this particular PIA may also facilitate more advanced sitting abilities and may enhance other gross motor skills using training in AT by developing other progressions similar to the TTC (e.g., such as for standing, walking, running, or treatment of other Central Nervous System - impairments). These additional motor skills were outside the scope of the present research focus, but future studies may explore these possibilities.

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Appendix

Qualitative Tool: Non-Directive Focused Interviews (NDFI)

Please read the answers to these questions on the tape recorder. If there any queries, or anything is unclear, please ask the researcher.

1. Describe how the child sits on a stool without support or assistance. The description will focus on the different parts of the body and their position.
2. Describe how the child sits on the stool unassisted and performs functions with hands-head coordination. Examples: cleaning the mouth, bringing a handkerchief to the mouth area, brushing hair, brushing teeth, eating, etc.
3. Describe whether the Therapeutic Treatment Chair device, enabling gradual exposure to gravity-conditions on land while seated, affected the child in any way.
4. Describe whether the intervention, or any other reason, in the life of the child led to any change during the research period?