Original Article

The Effect of Eight Weeks of Aquatic Exercises on Muscle Strength in Children with Cerebral Palsy: A Case Study

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Abstract

Background: Cerebral palsy in children is considered a non-progressive brain injury due to abnormal brain development. The aim of this study was to investigate the effect of eight weeks of aquatic exercises on muscle strength in children with cerebral palsy.

Materials and Methods: This study was performed on three boys with cerebral palsy with a mean age of 6.5 years. In this research, a single case study method with A1-B-A2 design has been used. After determining the position of the baseline, the intervention began and during 24 sessions of individual intervention, aquatic exercises were presented to the subjects and all three subjects were followed up for 2 consecutive weeks and one month after the end of the intervention. The strength of the flexor muscles of the arms and legs was measured by a power track dynamometer made by JTECK with a threshold of 4.4 N.

Results: Based on the indicators of descriptive statistics and visual analysis, the intervention was effective for all three participants in muscle strength, and the strength of individuals after the intervention has improved compared to the baseline stage (percentage). Information overlap for the first and second participant in the strength of right thigh flexors was 75% and for the third participant was 100%. The strength of the upper and lower torso muscles improved after the end of the training compared to the basic stage.

Conclusion: Aquatic exercises can increase the strength of children with cerebral palsy and provide a favorable environment for children with cerebral palsy.

Keywords: Cerebral palsy, exercises, hydrotherapy, muscle strength

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Introduction

Cerebral palsy is a group of developmental-motor disorders that are non-progressive and occur in a developing fetus or infant brain and continue throughout life.[1] Its prevalence in Iran is 2.06[2] and in other countries is about 2 per 1000 live births.[3] The rate has been stable in Western countries for the past two decades.[4] In this group of children, problems in posture and movement cause limitations in various life activities and the level of participation. On the other hand, defects in the proper functioning of the muscular system lead to conditions such as abnormal muscle tone, reduced control in selective movements.[1]

Dodd in 2003 considered muscle weakness to be a major problem for most patients with spastic cerebral palsy.[5] Andersson[6] clinically demonstrated in 2003 that reducing spasticity causes muscle weakness and abnormal movement

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patterns in most children, and therefore recommended muscle strengthening and coordination to improve motor function.

Researchers are always looking for appropriate strategies to support patients with cerebral palsy and reduce the various complications associated with it. In recent years, the effect of various sports exercises on this very common sensory-motor disorder has attracted the attention of many researchers. Among the main goals of exercise interventions for children with cerebral palsy are to reduce the effects of disorders in gross motor function, gait, aerobic capacity, functional strength, balance, andconsequently, reduce their limitations for activity and increase sports participation.[7] Children with a cerebral palsy score lower than healthy children in terms of physical and motor fitness, including strength and endurance.[8] Exercising in water is one of the methods that its use has grown significantly in the last two decades due to its benefits and has become a form of exercise therapy. Hydrotherapy can relieve the symptoms of the disease, as well as improve motor and cognitive abilities in many Help diseases.[9] Different training conditions in an aqueous environment reduce overload on the joints and prevent injury. Floating also allows one to perform exercises that one cannot do on the ground.[9] Water sports are safer and safer than land sports for such people because the anti-gravity buoyancy force in the water environment acts as a resistance force. The water environment is suitable for comfortable and easy movement of people with mobility problems on the ground. In addition, hydrostatic pressure during water immersion exerts an equal resistance on all active muscle groups. Therefore, the water environment can be suitable for resistance activities,[10] and it is recommended as an immune and complementary treatment in children with cerebral palsy.[11]

However, due to the fact that few studies have studied the effects of hydrotherapy exercises on the muscular strength of children with cerebral palsy on a case-by-case basis, and on the other hand, these studies have evaluated more young and elderly people and less studied children; Therefore, the present study was designed and conducted to investigate the effect of hydrotherapy exercises on muscle strength in children with cerebral palsy.

Materials and Methods

Study design and population

The method of the present study was a case-study based on individual analysis with purposive sampling. Three boys with cerebral palsy (two 7 years old and one 6 years old) from "Farda Physical-Mental Center" in Isfahan province using a medical record and consent of their parents, observing the entry and exit criteria as follows were chosen.

Inclusion and exclusion criteria

Inclusion criteria: 1- 6-7 years old age range, 2- being male, 3- ability to understand verbal commands, 4- lack of regular participation in water sports sessions at least 3 months before the intervention, 5- no orthopedic surgery in 1 year before the intervention, 6- do not inject botulism toxin for 6 months before the intervention, 7- no cardiovascular problems, 8- do not use sedatives during the intervention.

Exclusion criteria: 1- lack of cooperation between parents and children; 2- occurrence of orthopedic accidents during the intervention time.

Baseline measurements

The strength of the shoulder and thigh flexor muscles was measured by a JTECK Power Track Õ dynamometer with a threshold of 4.4 N. The strength of shoulder and thigh muscles in three hands was measured with 10-12 repetitions, which after 60 seconds of rest between each repetition; the average was calculated and recorded. The measurement was that the subject was sitting, the instrument was placed on the flexor muscles of her shoulder and thigh, and then the subject was asked to bend the shoulder and thigh according to a previously documented method.[12]

Intervention protocol

The design used in this study was A1-B-A2. Stage A1 involves gathering information before the intervention for four weeks; Phase B, the intervention phase consisted of eight weeks of training in water, and phase A2 included the follow-up phase or the secondary baseline phase, which included a period of two weeks.[13]

Children with cerebral palsy followed eight weeks of water training. This program replaced their usual treatment program. The exercise plan consisted of eight weeks of exercise, three sessions per week, and 60 minutes per session (with a day off between each exercise day), which was performed in the pool of the University of Isfahan under the supervision of a researcher. The training sessions were performed according to the American College of Sports Medicine (ACSM) guidelines, consisted of four sections, which included 5 to 10 minutes of warm-up, 15 to 20 minutes of stretching exercises for people with cerebral palsy, and 25 to 30 minutes of torso strengthening exercises, respectively and at the end of each session, people cooled for about 5 minutes.

In this study, to analyze the data, first, the raw data were plotted (for each subject, the data related to the three baseline positions, intervention, and follow-up were plotted on a graph, respectively). Then, the stability and trend compartment was plotted for the data diagram of all three subjects in the baseline and intervention positions. Then, using the trend and stability index, the degree of stability and direction of the data trend was determined. Between situational, the effectiveness of the independent and dependent variables was evaluated.

Results

The results of visual analysis of the graphs show that training in water in the intervention position compared to the baseline has increased the strength of the flexor muscles of the superior shoulder. The percentage of information overlap (PND) is

100% for the first and second participants and 75% for the third participant. Also, the findings of visual analysis of the data graphs of all three subjects showed an increase in the strength of the superior thigh flexor muscles (PND was 75% for the first and third participants and 100% for the second participant). Thus, the results of the degree of overlap between two adjacent positions (PND) showed that hydrotherapy exercises increased the strength of superior thigh flexors in the research sample in the intervention position relative to the baseline [Figures 1 and 2].

Table 1 shows the individual characteristics of the subjects. The findings of in-situ and inter-situ analysis are shown in Tables 2 and 3.

Discussion

The aim of this study was to evaluate the effect of a course of hydrotherapy exercises on muscle strength in children with cerebral palsy. The results showed that the strength of the shoulder flexor muscles in the baseline stage has a steady trend, but with the start of hydrotherapy, the strength of the shoulder flexor muscles in the first participant at the end of the second week is the same as the basal strength level and from the end of the second week to the end of the eighth week it was increased. The third participant experienced a significant increase in shoulder flexor muscle strength during the first three weeks of training, but it almost remained constant from the end of the sixth week until the end of the intervention phase. PND is 100% for the first and second participant and 75% for the third participant. Also, the findings of visual analysis of all three subjects showed an increase in the strength of the superior thigh flexor muscles (PND was 75% for the first and third participants and 100% for the second participant). Thus, the results of the degree of overlap between two adjacent positions (PND) showed that hydrotherapy exercises increased the strength of superior thigh flexors in the research sample in the intervention position relative to the baseline.

The strength of the flexor muscles at baseline was almost constant in all three subjects. Starting the exercises every two weeks showed that the strength of the flexor muscles of the thighs, subjects number one and two, decreased from the second week to the end of the fourth week and then increased until the end of the exercises. Also, in subject number three, muscle strength increased by the end of the eighth week, starting with the exercises. The strength of the flexor muscles of the shoulders and thighs decreased in the follow-up phase in all three subjects, but was still greater than in the baseline phase and the initial weeks of training.

In their review study, Fregala reported that water exercise for children with cerebral palsy could improve other factors by reducing the negative effects of poor balance.[14] In a study by Kelly *et al*.,[15] exercise in water increased muscle strength and improved the aerobic status of children with cerebral palsy, but conflicting results were obtained in terms of balance. While according to the research of Wadu *et al*.[16] and Shinost,[17] the nature of the water environment and its buoyancy effect, in addition to reducing the force of gravity and greater freedom of muscles to move and increase deep inputs, improve range of

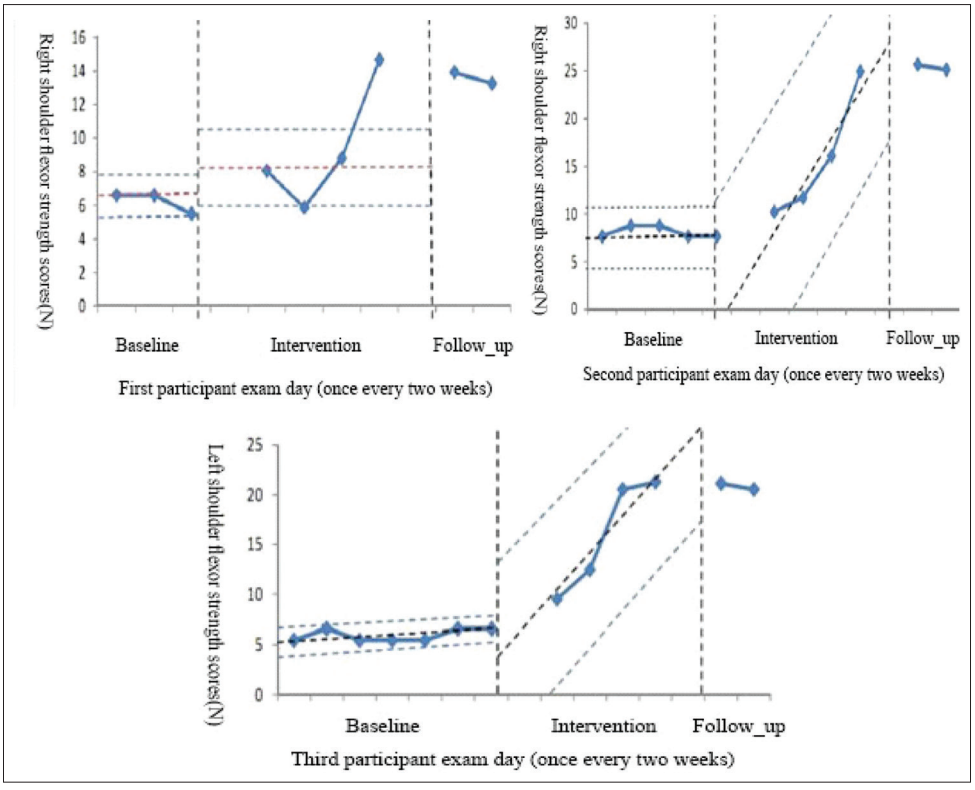

Figure 1: Superior shoulder flexor muscle strength for all three participants

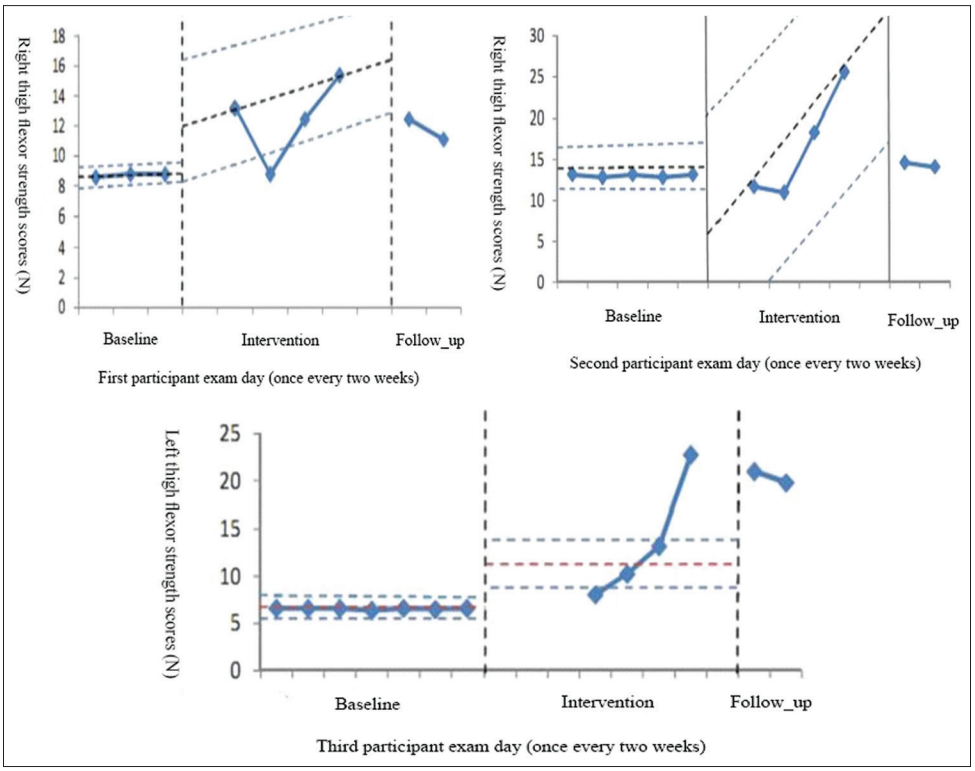

Figure 2: Superior thigh flexor muscle strength for all three participants

Table 1: Individual characteristics

Description	Height (cm)	Weight (kg)	Gender	Age	Test subject
Diplegia Spastic	110	18/5	Male	7	First
Hemiplegia	117	20	Male	7	Second
Spastic Diplegia	106	15	Male	6	Third

motion, and better maintain posture settings; the latter occurs especially due to water temperature. In hot water, the activity of the gamma nerve decreases with increasing body temperature, and this reduces the activity of the spindle, and as a result, facilitates muscle relaxation and reduces its stiffness, which in turn can affect the balance and muscle strength of people with cerebral palsy. Have a positive effect.[18] Dollings stated that the muscles of people with cerebral palsy suffer from a secondary muscle injury in which type b and IIa fibers decrease but type I fibers increase. However, the muscle strength caused by type II fibers is more prominent. Therefore, increasing strength can somehow indicate an increase in muscle volume and conversion of type II to I fibers.[19]

Similarly, Getz *et al*.[20] showed that children with more severe motor dysfunction, as classified by the GMFCS, may display superior performance in aquatic environments compared to their performance on land, which is consistent with our findings, who are restricted in their ability to perform many activities on land. One possible reason for this may be the thermal and mechanical effects of aquatic exercise.[21] The mechanical properties of the aquatic environment offer benefits by decreasing the effect of gravity and joint loading, optimizing postural control, and muscle strength. The viscosity of the water allows for fluid movement patterns to be experienced. Clapham *et al*.[22] have argued that these factors improve neuromuscular coordination, muscle endurance, and aerobic capacity. In addition, the increased unloading of body weight may facilitate an increase in muscle strength, thus allowing children to initiate movements that are more restricted on land.[23,24]

Daly *et al*.[25] showed in their study that the type of exercise is very important in improving the muscular strength of patients with cerebral palsy, and this issue should be considered when prescribing exercise. Also, children with CP are more likely to have lower levels of physical activity than their peers, which has negative implications for their health. However, aquatic exercise can be used to improve levels of fitness among children with CP.[26]

So far, there is little evidence to identify the best exercise protocol that includes the intensity, repetition, and duration of activity for children with cerebral palsy.[27] However, the response of age groups and different types of cerebral palsy to resistance training has not been fully studied. In the past, strength training was prohibited in patients with cerebral palsy because it was thought that these exercises increased muscle stiffness and thus increased spasms and range of motion of the joint.[28] Recent studies, however, show that there is no change in muscle spasms during and after strength training, and there is not even a ban on using these exercises in people with spasms.[29]

Table 2: Within and between position analysis for right hip flexion for all three participants

Between positions				Within positions						
B A			Position comparison subject	B			A			Sequence of positions subject
3rd	2nd	1st		3rd	2nd	1st	3rd	2nd	1st	
			Variation pattern	4	4	4	7	5	3	Length of positions
			Change of direction					Level		
positive	positive	Positive	Targeted effect	11/73	15/03	14/3	11	13/2	8/8	median
stable-stable	stable-stable	stable-stable	Change of stability	13/74	16/66	12/46	10/76	13/06	8/7	mean
			Change of level	10/26-21/26	11-25/6	8/8-15/4	10/4-11/3	12/87-13/2	8/6-8/8	Range of changes
16/86-11	21/96-13/2	13/93-8/8	Relative change	stable	stable	stable	stable	stable	stable	Stability envelope's range of changes
21/26-11	25/6-13/2	15/4-8/8	Absolute change					Level change		
11/73-11	15/03-13/2	14/3-8/8	Median change	16/86-10/63	21/96-11/36	11-13/93	10/7-11	13/2-13/03	8/8-8/6	Relative change
13/74-10/76	16/66-13/06	12/46-8/7	Mean change	21/26-10/26	25/6-11/73	13/2-15/4	11-11	13/2-13/2	8/8-8/6	Absolute change
			Data overlap							pattern
75%	100%	75%	PND	ascending	ascending	descending	equal	equal	equal	direction
25%	0%	25%	POD	stable	stable	stable	stable	stable	stable	stability
				No	No	No	No	No	No	Multiple paths

Table 3: Within and between position analysis for right shoulder flexion for all three participants

Between positions				Within positions						
B A			Position comparison Subject	B			A			Sequence of positions subject
3rd	2nd	1st		3rd	2nd	1st	3rd	2nd	1st	
			Variation pattern	4	4	4	7	5	3	Length of positions
			Change of direction					Level		
positive	positive	positive	Targeted effect	13/19	13/93	8/43	8/8	7/7	6/6	median
stable-stable	stable-stable	stable-stable	Change of stability	12/09	15/76	9/34	8/64	8/14	6/23	mean
			Level change	4-13	15-12	4-10	7/7-8/8	7/7-8/8	5/5-6/6	Range of changes
13/19-8.8	20/53-8/8	11/73-6/4	Relative change	stable	Stable	stable	stable	stable	stable	Stability envelope's range of changes
13/93-8/8	24/93-7/7	14/66-6/6	Absolute change							Level change
13/19-8/8	13/93-7/7	8.43-6/6	Median change	10/99-13/19	10/99-20/05	6/96-11/73	8/8-8/8	8/8-8/8	5/5-6/6	Relative change
12/09-8/14	15/76-8/14	9/34-6/23	Mean change	8/06-13/93	10/26-24/93	8/06-14/66	8/8-8/8	7/7-7/7	5/5-6/6	Absolute change
			Data overlap							pattern
75%	100%	100%	PND	ascending	ascending	ascending	equal	equal	equal	direction
25%	0%	0%	POD	stable	Stable	stable	stable	stable	stable	stability
				No	No	No	No	No	No	Multiple paths

A study by Retarekar *et al*. evaluated the effects of a water-based aerobic exercise program on a child with cerebral palsy.[29] Significant improvements in participation, activity, functional abilities, endurance, and gait were observed. These findings indicate that an aerobic exercise program in water is effective for a child with cerebral palsy and supports the need for further research in this area.[30]

In children with cerebral palsy, the combination and use of controlled reflex movement patterns and muscle activity may cause shortening of muscles, tendons, and ligaments. Therefore, their compensatory movements create an abnormal physical posture that prevents the development of motor skills in the long run. Due to muscle weakness and spasms, this group of people have difficulty performing activities such as walking and running independently and their participation in physical activity is reduced.[31] The benefits of using hydrotherapy depend on its anti-gravity and buoyancy position. Therefore, it can help to lose weight and reduce the compressive forces on the joints. As a result, the treatment promotes active and easier movements for children who are unable to perform some ground activities. Finally, due to the effects of hydrostatic water pressure, hydrotherapy can reduce muscle spasticity and improve the endurance of multisensory stimuli and increase blood circulation.[32]

The hydrotherapy program had positive effects on the body function and structure of children and adolescents with cerebral palsy. It can also strengthen the function of the heart, arteries, and muscles and reduce energy consumption while walking. Hydrotherapy program reduces spasticity of hip joints and knee flexors.[33] It was also found that the hydrotherapy program causes a significant increase in parameters related to walking speed, stride length, increase in strength, range of motion, and cardiovascular endurance in children with cerebral palsy.[32] Therefore, it can be used as an alternative but safe treatment even in children with cerebral palsy, whose ability to perform ground training is limited.[34] Group hydrotherapy exercises help to improve the ability to walk in adolescents with cerebral palsy by creating a balance of functions between the heart and the respiratory system and reducing the rate and number of heartbeats.[28] The most important effects of hydrotherapy in patients with cerebral palsy are increased concentration, muscle strength, balance, the increased threshold of touch, onset, and maintenance of eye contact.[35] In addition, hydrotherapy also has positive effects on gross motor functions such as jumping, running, and walking.[35] The use of hydrotherapy exercises along with resistance training was also useful in strengthening endurance and muscle strength.[36]

Improving the important components of muscle strength and balance, which are the primary disorders in children with cerebral palsy, seems to increase self-confidence, strengthen muscles, and children's participation in daily activities and social relationships. However, this study, with some limitations, such as the small number of samples, was a more accurate assessment of the need for more advanced instruments such as electromyography, which unfortunately could not be used due to instrumental and costly conditions. In addition, each participant, due to their specific circumstances, had to have their own occupational therapist, which was also not possible due to limited staff.

The results showed that hydrotherapy exercises increased muscle strength in children with CP. Part of the increase in strength can be attributed to an increase in muscle mass and part to anabolic hormones. However, the increase in strength due to muscle volume and filament conversion has not been well demonstrated and these factors were not investigated in this study. It seems that by examining muscle volume using the magnetic resonance imaging (MRI) method, it is possible to determine the effect of muscle volume on muscle strength.

Conclusion

The results of the present study showed that hydrotherapy exercises can be effective in improving the muscle strength of the flexor muscles of the shoulders and thighs of children with cerebral palsy, so these exercises can be considered as an important strategy to increase muscle strength due to increased volume. Muscle and other anabolic hormone stimulants are recommended for people with cerebral palsy who have weak muscles and reduced flexibility. They concluded that hydrotherapy could be used in children and adolescents. Exercises, their duration, and intensity should be determined based on the physical and cognitive condition of patients. Hence, it is suggested that further studies in this field are very necessary.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

References

1. Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M, Damiano D, *et al*. A report: The definition and classification of cerebral palsy April 2006. Dev Med Child Neurol Suppl, 2007;109(suppl 109):8-14.
2. Johnson A. Prevalence and characteristics of children with cerebral palsy in Europe. Dev Med Child Neurol 2002;44:633-40.
3. Dalvand H, Dehghan L, Hadian MR, Feizy A, Hosseini SA. Relationship

between gross motor and intellectual function in children with cerebral palsy: A cross-sectional study. Arch Phys Med Rehabil 2012;93:480-4.
4. Surman G, Hemming K, Platt MJ, Parkes J, Green A, Hutton J, *et al*. Children with cerebral palsy: Severity and trends over time. Paediatr Perinat Epidemiol 2009;23:513-21.
5. Dodd KJ, Taylor NF, Graham HK. A randomized clinical trial of strength training in young people with cerebral palsy. Dev Med Child Neurol 2003;45:652-7.
6. Nikolaos C, Emmanouil S, Eirini G, Aggeliki D. The effect of a functional progressive strength training program on mobility of ambulatory adolescents and young adults with cerebral palsy. Sports Med Rehabil J 2019;4:1046.
7. Cherng RJ, Su FC, Chen JJ, Kuan TS. Performance of static standing balance in children with spastic diplegic cerebral palsy under altered sensory environments. Am J Phys Med Rehabil 1999;78:336-43.
8. Ferland C, Lepage C, Moffet H, Maltais DB. Relationships between lower limb muscle strength and locomotor capacity in children and adolescents with cerebral palsy who walk independently. Phys Occup Ther Pediatr 2012;32:320-32.
9. Bairaktaridou A, Lytras D, Kottaras A, Iakovidis P, Chatziprodromidou IP, Moutaftsis K. The effect of hydrotherapy on the functioning and quality of life of children and young adults with cerebral palsy. Int J Adv ResMed 2021;3:21-4.
10. Roth AE, Miller MG, Richard M, Ritenour D, Chapman BL. Comparisons of static and dynamic balance following training in aquatic and land environments. J Sport Rehabil 2006;15:299-311.
11. Lai C-J, Liu W-Y, Yang T-F, Chen C-L, Wu C-Y, Chan R-C, *et al*. Pediatric aquatic therapy on motor function and enjoyment in children diagnosed with cerebral palsy of various motor severities. J Child Neurol 2015;30:200-8.
12. Drumm M, Fabiano J, Lee E, Jezequel J, Rao AK, Yoon L. Effects of power training on gait, power, and function in children with cerebral palsy. Phys Occup Ther Pediatr 2021;22:1-15.
13. Peungsuwan P, Parasin P, Siritaratiwat W, Prasertnu J, Yamauchi J. Effects of combined exercise training on functional performance in children with cerebral palsy: A randomized-controlled study. Pediatr Phys Ther 2017;29:39-46.
14. Fragala-Pinkham MA, Smith HJ, Lombard KA, Barlow C, O'Neil ME. Aquatic aerobic exercise for children with cerebral palsy: A pilot intervention study. Physiother Theory Pract 2014;30:69-78.
15. Kelly M, Darrah J. Aquatic exercise for children with cerebral palsy. Dev Med Child Neurol 2005;47:838-42.
16. Wadu Mesthri S. The effects of an individual hydrotherapy program on static and dynamic balance in children with cerebral palsy in Sri Lanka. 2019.
17. Shinost CA, Pratt LE, Smith K. A combination of manual therapy, movement systems, and biopsychosocial approaches for the treatment of upper limb adverse neural tissue tension: A case report. Open Access Lib J 2017;4:1-28.
18. Hayes K, Ginn KA, Walton JR, Szomor ZL, Murrell GA. A randomised clinical trial evaluating the efficacy of physiotherapy after rotator cuff repair. Aust J Physiother 2004;50:77-83.
19. Dollings H, Sandford F, O'conaire E, Lewis JS. Shoulder strength testing: The intra-and inter-tester reliability of routine clinical tests, using the PowerTrackTM II commander. Shoulder Elbow 2012;4:131-40.
20. Güeita-Rodríguez J, Lidiane Lima Florencio JL, Arias-Buría JL, Lambeck J, Fernández-de-Las-Peñas C, Palacios-Ceña D. Content comparison of aquatic therapy outcome measures for children with neuromuscular and neurodevelopmental disorders using the international classification of functioning, disability, and health. Int J Environ Res Public Health 2019;16:4263.
21. Lai CJ, Liu WY, Yang TF, Chen CL, Wu CY, Chan RC. Pediatric aquatic therapy on motor function and enjoyment in children diagnosed with cerebral palsy of various motor severities. J Child Neurol 2015;30:200-8.
22. Clapham ED, Lamont LS, Shim M, Lateef S, Armitano CN. Effectiveness of surf therapy for children with disabilities. Disabili Health J 2020;13:100828.
23. Sony SK, Gayathri A, Pravallika D, Basha SAJ, Ramana KV. An overview on rehabilitation and therapeutic benefit of aquatic therapy. International Journal of Alternative and Complementary Medicine Med 2021;9:20-4.
24. Ballington SJ, Naidoo R. The carry-over effect of an aquatic-based intervention in children with cerebral palsy. Afr J Disabil 2018;7:361.
25. Daly C, Lafferty E, Joyce M, Malone A. Determining the most effective exercise for gluteal muscle activation in children with cerebral palsy using surface electromyography. Gait Posture 2019;70:270-4.
26. McPhee PG, Verschuren O, Peterson MD, Tang A, Gorter JW. The formula for health and well-being in individuals with cerebral palsy: Cross-sectional data on physical activity, sleep, and nutrition. Ann Rehabil Med 2020;44:301-10.
27. Kisner C, Colby LA, Borstad J. Therapeutic Exercise: Foundations and Techniques. 2017: Fa Davis.
28. Fragala-Pinkham MA, Dumas HM, Barlow CA, Pasternak A. An aquatic physical therapy program at a pediatric rehabilitation hospital: A case series. Pediatr Phys Ther 2009;21:68-78.
29. Retarekar R, Fragala-Pinkham MA, Townsend EL. Effects of aquatic aerobic exercise for a child with cerebral palsy: Single-subject design. Pediatr Phys Ther 2009;21:336-44.
30. Esmailiyan M, Marandi SM, Esfarjani F. Effect of a period of resistive and balance exercises on the balance of cerebral palsy children: A case study. J Exercise Sci Med 2014;6:153-66.
31. Franzen K, Tryniszewski P. Effectiveness of Aquatic Therapy for Children with Neurodevelopmental Disorders: A Systematic Review of Current Literature. Sage Colleges; 2013.
32. Chrysagis N, Douka A, Nikopoulos M, Apostolopoulou F, Koutsouki D. Effects of an aquatic program on gross motor function of children with spastic cerebral palsy. Biol Exercise 2009;5:13-25.
33. Ballaz L, Plamondon S, Lemay M. Group aquatic training improves gait efficiency in adolescents with cerebral palsy. Disabil Rehabil 2011;33:1616-24.
34. Clutterbuck G, Auld M, Johnston L. Active exercise interventions improve gross motor function of ambulant/semi-ambulant children with cerebral palsy: A systematic review. Disabil Rehabil 2019;41:1131-51.
35. Gorter JW, Currie SJ. Aquatic exercise programs for children and adolescents with cerebral palsy: What do we know and where do we go? Int J Pediatr 2011;2011:712165.
36. Badawy WM, Ibrahem MB. Comparing the effects of aquatic and land-based exercises on balance and walking in spastic diplegic cerebral palsy children. Med J Cairo Univ 2019;84:1-8.