ORIGINAL PAPER

Physiotherapy Quarterly (ISSN 2544-4395)
2023, 31(4), 81–86

Efficacy of aquatic exercise on pulmonary function and aquatic skills performance in older children with cerebral palsy. Randomised controlled study

DOI: https://doi.org/10.5114/pq.2023.125166

Ashraf Abdelaal Mohamed Abdelaal[1], Doaa Tammam Atia[2,3]

[1] Department of Physical Therapy for Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Egypt

[2] Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Heliopolis University, Cairo, Egypt

[3] National Institute of Neuromotor System, General Organization for Teaching Hospitals and Institutes, Cairo, Egypt

Abstract

Introduction. To evaluate the effectiveness of aquatic aerobic exercise training (AqET) on the pulmonary function (PF) and aquatic skills performance in older children with spastic cerebral palsy (CP). A randomised controlled study.

Methods. Twenty-eight children, 13–15 years old, with spastic CP were randomly allocated into an AqET group (n = 13; received AqET plus a traditional physiotherapy 'TPT' program) and a control group (n = 15; received TPT only). The PF [including (forced vital capacity; FVC), (forced expiratory volume in one second; FEV1)] and the aquatic skills performance (including the WOTA mental adaptation score 'WMA', the WOTA skills balance control movement score 'WSBM', the WOTA total score 'WTOT') were evaluated at the beginning and after 12 weeks.

Results. Post-study results revealed significant increases in the PF, WMA, WSBM, WTOT mean values in both groups. The FEV1% and FVC% mean values and percentages of changes were [84.00% (21.5%), 78.23% (24.56%)] and [(71.13% (6.9%), 62% (7.12%)] for the AqET and control groups, respectively. The WMA, WSBM, WTOT mean scores and percentages of changes were [33.15 (77.01%), 15.46 (643.27%), 48.62, (133.19%)] and [20.2 (7.59%), 2.27 (23.89%), 22.47 (7.36%)] for the AqET and control groups, respectively ($p < 0.05$). There were significant differences between groups in the PF and the aquatic skills performance post-study, in favour of the AqET group.

Conclusions. Children with spastic CP benefit favourably from AqET or TPT programs. The AqET is more beneficial than the TPT in increasing the PF and aquatic skills performance in older children with spastic CP.

Key words: hydrotherapy, exercise, lung volume measurements, children, cerebral palsy

Introduction

Cerebral Palsy (CP) is a group of disorders caused by non-progressive immature brain damage, resulting in variable degrees of physical disabilities among children [1]. Physiological classification of the CP is based on the site of the brain lesion causing the motor disorder and is categorised into either pyramidal (spastic type; accounts for about 70–80% of all CP cases) or extra-pyramidal (non-spastic type; accounts for about 20–30% of all CP cases) [2, 3]. Another topographic classification considered the predominant motor disturbances and the pattern of limb involvement, categorising the cerebral palsy into many patterns including monoplegia (involvement of one limb), diplegia (involvement of both upper limbs), triplegia (involvement of three limbs), hemiplegia (involvement of both upper and lower limbs of the same side) and quadriplegia (involvement of the four limbs) [3].

Hemiplegia and diplegia are the most commonly encountered CP types according to the motor impairment's topographic distribution [4]. Retarded motor activation and physical inactivity are major contributors to the abnormally reduced functional performance and aerobic capacity commonly encountered in children with CP compared to their healthy peers [5].

The CP-induced weakness or paralysis of the skeletal muscles, decreased activity level, delayed cardiopulmonary system development, and retarded physical activities are all associated with respiratory dysfunction and reduced functional capacity [6, 7]. Pulmonary complications are among the primary causes of hospitalisation [8], and deteriorated quality of life in severe CP cases [9].

Such respiratory disorders are the most common cause of morbidity and mortality [10], with respiratory failure recognised as the primary cause of death among patients with CP [11]. Patients with CP are at an increased risk for recurrent chest infection, pneumonia, atelectasis and chronic respiratory failure [12]. Patients with spastic CP are usually encountered with reduced chest wall mobility, chest shape abnormalities, and weak respiratory muscles that predispose them to abnormally reduced pulmonary functions (PF) compared to their normal peers [13]. Both obstructive and restrictive PF abnormalities are commonly seen in patients with CP [14].

Aquatic exercise training (AqET) is one of the most useful approaches in the treatment of children with CP [15] The ease of performing the aquatic exercises allows children with CP to perform body movements that are difficult on the ground and so augments many physiological and psychological parameters [15, 16].

Varieties of AqET approaches have been described [17–19], with the task-based techniques more preferable because they facilitate movements, enhance sensory inputs, encourage active participation of the child [17, 18] and improve physical performance and vital capacity in children with CP [15]. Although beneficial physical and physiological effects of AqET

Correspondence address: Ashraf Abdelaal Mohamed Abdelaal, Department of Physical Therapy for Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Cairo, Egypt, e-mail: drashraf_pt79@yahoo.com; https://orcid.org/0000-0003-1319-7108

Received: 27.01.2022
Accepted: 10.06.2022

Citation: Abdelaal AAM, Atia DT. Efficacy of aquatic exercise on pulmonary function and aquatic skills performance in older children with cerebral palsy. Randomised controlled study. Physiother Quart. 2023;31(4):81–86; doi: https://doi.org/10.5114/pq.2023.125166.

in children with CP have been shown, more research is still warranted in this area [20] and randomised-controlled studies comparing the effects of adding AqET to the traditional care program of children with CP are needed [21]. The objective of this study was to evaluate the effects of AqET on the PF and aquatic task performance in older children with CP.

Subjects and methods

Research design

This study followed the randomised controlled study design, adhered to the principles of the Declaration of Helsinki 1975, revised in 2000, and was approved by the ethics committee of the General Organization for Teaching Hospitals and Institutes (approval number INM00032). Initially, the parents signed an informed consent for voluntary participation, enrolment and agreeing to publication of the study results. This study took place from May 2020 to September 2021.

Subjects

Thirty-Seven children diagnosed with spastic CP were recruited from the National Institute of Neuromotor System. Initially, nine patients were excluded for a variety of reasons, including distance and transportation barriers ($n = 2$), a lack of interest ($n = 4$), and recent use of bronchodilators ($n = 3$). After baseline screening, the 28 (11 male, 17 female) eligible children with spastic CP were randomly allocated via a simple random sampling technique (probability sampling) using an online random number generator (http://www.randomization.com) into one of two groups: the aquatic aerobic exercise training group (AqETG; $n = 13$) and the control group (CG; $n = 15$) (Figure 1).

Inclusion criteria

Children diagnosed with spastic CP (diplegia and hemiplegia), aged 13–15 years old, able to follow instructions, able to walk with or without assistive ambulatory aid, with Gross Motor Function Classification System (GMFCS) scores I and II, not previously included in any form of regular AqET, and able to follow instructions were all included in this study.

Exclusion criteria

Children with neurological / psychiatric disorders other than the CP, with a recent history of botulinum toxin injection within the last three months, with orthopaedic surgery within the last six months, with a GMFCS score of IV or V, children with open wounds, with acute cardiorespiratory or other systemic disorders, receiving medications that affect the performance and accuracy of the evaluations' results (e.g., bronchodilators) were all excluded at the beginning of study.

Study procedures

After parental approval, all children underwent the same medical screening and evaluation protocols, including initially a full history taking and physical assessment, followed by an assessment of the child's ventilatory functions (VF) and aquatic skills performance. All participants / parents were informed they were free to withdraw at any time throughout the study. A preliminary power analysis was conducted to determine the proper sample size using an online G-Power program with (1-β error probability) = 0.95, alpha error probability = 0.05, effect size = 0.7, number of groups = 2, determining a sample size of 28 participant to produce reliable results.

Outcome measures

The main outcome variables were the VF (including the forced vital capacity 'FVC', forced expiratory volume in one second 'FEV1', FEV1/FVC, peak expiratory flow 'PEF') and the aquatic skills performance (evaluated by the Water Orientation Test Alyn 2 (WOTA 2). The variables were evaluated pre-study (evaluation-1) and after 12 weeks (evaluation-2), preceded by two non-training days to avoid the interference of the 'acute post-exercise effects' on the study results. All tests were standardised for all participants and each therapeutic intervention was conducted by an experienced therapist. A preliminary educational session was conducted to ensure the participants properly recognised the evaluation procedures and treatment protocols. The utilised instruments were periodically checked and calibrated according to the manufactured guidelines.

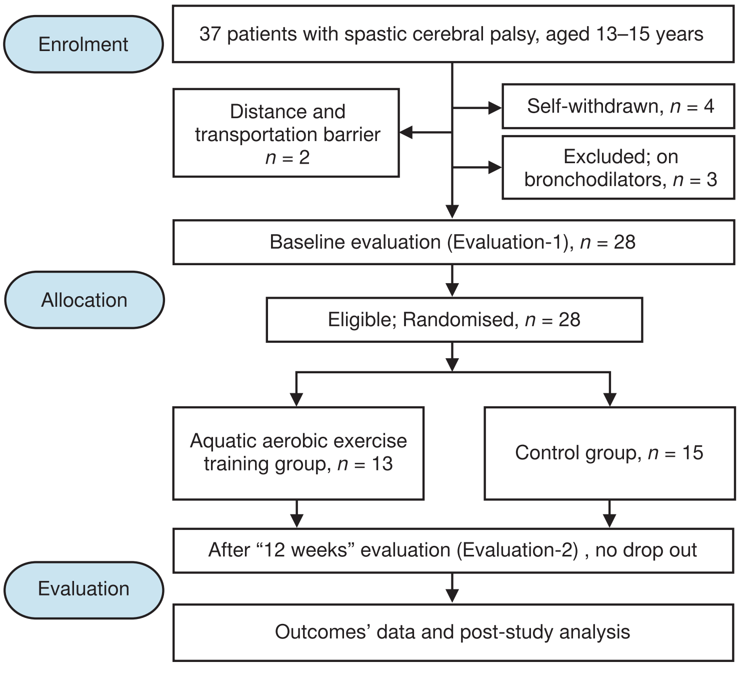


Figure 1. Patients' flowchart

Participants' demographic characteristics

Basic characteristics of all participants were collected according to the standard procedures. While wearing light, comfortable clothes, weight in kg and height in metres were evaluated using a portable stadiometer (ProMed® 6129, USA) while the child was standing erect. BMI in kg/m^2 ($weight/height^2$) was also calculated. Each participant's GMFCS score was evaluated to determine the present gross motor function according to previously described guidelines [22].

Ventilatory functions assessment

To ensure reliability of the assessment procedure, the VFs of all children with CP were evaluated by the same therapist using a portable computerised PF testing unit (Spiro Analyzer STR 250, Japan). After 10 minutes of rest, the VF was evaluated for each child following the previously described protocol [23]. Clear instructions were simplified and explained step-by step for each child. After three normal breaths, each child was encouraged to inspire then expire air as deeply and rapidly as possible through the mouthpiece while nose clips were in place. Each child was continuously directed to tightly hold the disposable mouthpiece with his or her lips to prevent air leakage. The procedure was repeated three times with sufficient rest time in between and the best readings of the FVC, FEV1, FEV1/FVC and PEF were then recorded.

Aquatic skills performance assessment

Water Orientation Test Alyn 2 (WOTA 2) is a valid and reliable test [24], used to assess the child's level of mental adjustment and function in water (balance control and movement). The WOTA 2 is a several-skills test and is based on the principles of the Halliwick concept's 10-point program. The therapist simply explained the required task verbally and demonstrated it to the child, who was then encouraged to perform each task three times. The therapist scored the child's performance on a 4-point scale, where '0' indicated that the child did not perform the task or did not cooperate in spite of his or her ability to do so, and '3' indicated independent performance of the task with or without the therapist's supervision. If a conflict arose between two scores, the lower score was chosen. The Wota mental adaptation (WMA) score, the Wota skills balance control movement (WSBM) score and the Wota total score (WTOT) score were calculated according to the previously described procedure [25].

Interventions

Both interventions were designed to maximise the participants' enjoyment and benefits, to minimise the chance of the child dropping out.

Aquatic aerobic exercises training (AqET)

Thirteen children received the moderate-intensity AqET program following the previously established protocol [26], in addition to the TPT recently described by Atia and Tharwat [27].

Participants in the AqETG received a 60-minute AqET session, 3 times/week, for 12 successive weeks in the swimming pool (70–180 cm depth, 4 × 6 m area). Each AqET session was performed with a one-to-one therapist-patient ratio, preceded and ended by a 10-minute warm-up and cool-down (at 50–60% training intensity) and composed of 40 minutes of AqET (at 70–80% training intensity), with a 27.7°C water temperature. The AqET intensity was checked each 10 minutes from the participant's index figure, using a pulse oximeter (CMS50DL, China).

The warm-up and cool-down phases were composed of light-intensity in-water exercises (slow walking and stretching exercises for the large muscle groups). The AqET included five minutes of each of the following tasks: walking, shuttle running, jumping, deep water running, creeping, kicking, swimming, ball and chasing games.

The AqET intensity was adjusted according to the aquatic target heart rate (THR) training formula, [28] using the resting heart rate (RHR), where:

$$\text{THR zone} = 50\% \text{ to } 80\% \, [(200 - \text{age}) - \text{RHR}] + (\text{RHR}) - 17$$

Control group (CG; *n* = 15)

Fifteen children received only the TPT previously described by Atia and Tharwat [27], which included neurodevelopmental techniques, stretching exercises for the major muscle groups, postural correction exercises, gait training exercises, and balance and breathing exercises.

Statistical analysis

SPSS version 20 (SPSS Inc, Chicago, IL) was used for the statistical analysis. The normality of the data distribution was checked by the Kolmogorov–Smirnov test. Continuous data was presented as mean ± *SD*, while categorical data was expressed as frequency and percentages. The VF and the aquatic skills' related assumptions were evaluated within-groups using the paired *t*-test and between-groups using the one-way ANOVA, and Bonferroni testing was used for the post-hoc analysis. *P*-value < 0.05 was accepted as statistically significant.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the General Organization for Teaching Hospitals and Institutes (approval No.: INM00032).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

The VF and the aquatic skills performance were evaluated pre- and post-study. Initially, there were non-significant statistical differences between-groups in the evaluated variables and the children's demographic characteristics ($p > 0.05$) (Table 1).

Demographic characteristics

There were non-significant differences in age (year; $p = 0.71$), body weight (kg; $p = 0.4$), height (m; $p = 0.72$), body mass index (kg/m^2; $p = 0.48$), GMFCS ($p = 0.44$), and sex distribution ($p = 0.96$) between-groups at the beginning of the study (Table 1).

Table 1. Demographic characteristics of participants in all groups

Variables		AqETG (n = 13)	CG (n = 15)	p-value
Sex	male	8 (61.5%)	9 (60%)	0.96**
	female	5 (38.5%)	6 (40%)	
GMFCS	1	4 (30.8%)	2 (13.3%)	0.44**
	2	9 (69.2%)	13 (86.7%)	
Age (year, mean ± SD)		13.85 ± 0.8	13.73 ± 0.8	0.71**
Weight (kg, mean ± SD)		48.39 ± 4.13	46.8 ± 5.36	0.4**
Height (m, mean ± SD)		1.52 ± 0.06	1.51 ± 0.05	0.72**
BMI (kg/m^2, mean ± SD)		20.98 ± 1.01	20.53 ± 2.05	0.48**

AqETG – aquatic aerobic exercises training group, CG – control group, GMFCS – Gross Motor Function Classification System level of significance at $p < 0.05$, ** non-significant

Within-group comparison

Post-study results revealed that there were significant increases in mean values of the FEV1 (p = 0.00) and FVC (p = 0.00) in the AqET group. Also, there were significant increases in mean values of the FEV1 (p = 0.00) and FVC (p = 0.00) in the control group.

Post-study, the FEV1, FVC, FEV1/FVC mean values were (84.00%, 78.23%, 107.09%) and (71.13%, 62%, 108.97%), while the FEV1, FVC, FEV1/FVC percentages of changes were (21.5%, 24.56%, 2.84%) and (6.9%, 7.12%, 1.42%) for the AqET and control groups, respectively.

There were significant increases in the mean values of the WMA (p = 0.00), WSBM (p = 0.00), and WTOT (p = 0.00) in the AqET group. There were significant increases in the WMA (p = 0.00), and WTOT (p = 0.0002), with non-significant increases of the WSBM (p = 0.55) in the control group.

Post-study, the WMA, WSBM, WTOT mean scores were (33.15, 15.46, 48.62) and (20.2, 2.27, 22.47), while the WMA, WSBM, WTOT percentages of changes were (77.01%, 643.27%, 133.19%) and (7.59%, 23.89%, 7.36%) for the AqET and control groups, respectively ($p < 0.05$).

Between-groups comparisons

Pre-study results revealed that there were non-significant differences between groups in the FVC% (p = 0.07), and FEV1% (p = 0.14). There were also non-significant differences between groups in the WMA (p = 0.97), WSBM (p = 0.88), and WTOT (0.86).

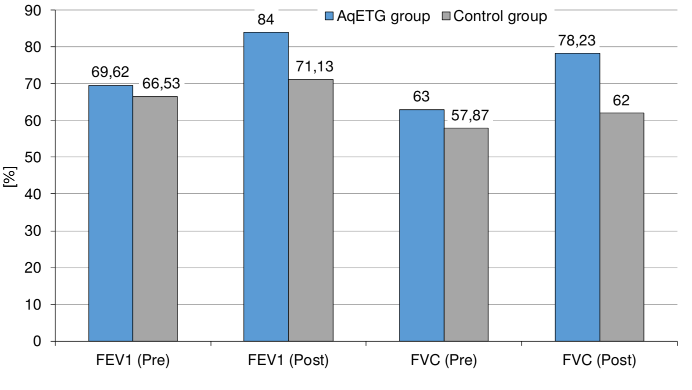
Post-study, there were significant differences in the ventilatory function and the aquatic skills performance mean values, in favour of the AqET group ($p < 0.05$). There were also significant differences in the FVC% (p = 0.00), FEV1% (p = 0.0001), WMA (p = 0.00), WSBM (p = 0.00), and WTOT (p = 0.00) (Figure 2, 3).

Discussion

This study investigated the effectiveness of AqAE on the VF and aquatic skills performance in the older children with spastic CP. Both the AqAE and the TPT training improved the VF and the aquatic skills performance in the older children with spastic CP. Furthermore, the AqET training was more beneficial in increasing the VF and the aquatic skills performance in the older children with spastic CP.

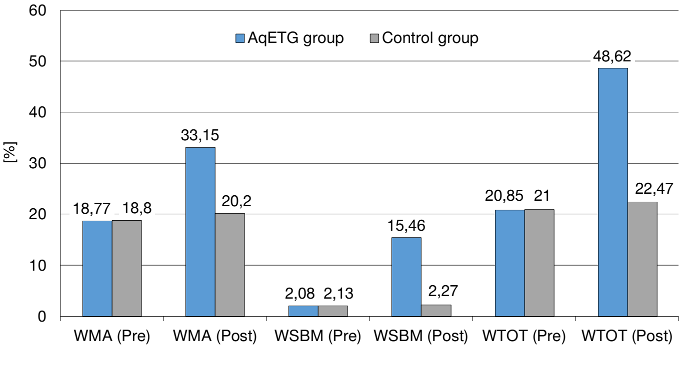
The AqET program proved effective in strengthening the weak muscles, increasing the range of motion, and enhancing the circulation and lung function. [29] This can be attributed to the unrestrained movements, overcoming the gravitational constrains, and the ease of use of muscles in patients with CP [30].

Improvement in the strength of the respiratory muscles and increased chest expansion are the main contributors to increased pulmonary functions in patients with CP after the rehabilitation program [31]. The obvious improvement in the pulmonary function in response to exercise training can be also attributed to the patient's increased ability to expand



AqETG – aquatic aerobic exercises training group
FEV1 – forced expiratory volume in one second
FVC – forced vital capacity

Figure 2. Between-groups comparison of ventilatory function



AqETG – aquatic aerobic exercises training group
WMA – WOTA mental adaptation score
WSBM – WOTA skills balance control movement score
WTOT – WOTA total score

Figure 3. Between-groups comparison of aquatic skills performance

the chest wall, since it is abnormally reduced in the patient with CP [32].

A previous study by Lai et al. [33] reported that an aquatic therapy program for children with spastic CP can effectively improve gross motor function more than the conventional therapy even in children with very limited ability to perform activities.

Children with spastic CP benefit from the more playful nature and the limited effort non-weight-bearing exercises performed during the aquatic therapy program, which provides more pain-free activities compared with the conventional training programs [34].

Aquatic therapy motivates children and encourages their engagement in the exercise program [35], reduces joint loading, minimises muscular fatigue and facilitates functional training in children with spastic cerebral palsy [36].

Children with spastic cerebral palsy manifest abnormal joint alignments and muscle contractures secondary to spasticity and muscle weakness, resulting in increasing activity-related pain and limitations that alter their physical performance [37].

The average increase of the WMA (152.23%), WSBM (150.96%), and WTOT (147.72%) in this study is higher than that found in the study of Declerck et al. [21] (16.85%), (17.35%), (17.15%) and Jorgić et al. [38] (26.73%), (34.01%), (25.23%) for WMA, WSBM, WTOT, respectively. The shorter study duration of six weeks and smaller sample size used in the previous studies compared to the longer (12 weeks of training) and relatively larger sample size used in the current study, the differences in the participants' ages and the GMFCS levels as well as the training frequency can all explain these differences.

Improvements in evaluated variables within the aquatic training group can be attributed to the increased activity status achieved during the AqET program since the hydrostatic pressure of the water reduces the spasticity and the lower limb joints' compressive forces, improves blood circulation and enhances the motor function, which cannot be easily performed on land in patients with CP [39]. Furthermore, the properties of water and buoyancy help in supporting the child's weight, and maintaining the anti-gravity position, which facilitates movements and activity performance compared with the on-ground status [40].

Limitations

Although positive results were achieved, certain limitations arise in this study. The relatively-small number of participants and involvement only of GMFCS levels I and II limit the generalisability of the results, while the inability to follow the double-blind study design was another limitation. Further studies are required to overcome these limitations.

Conclusions

Children with spastic CP benefit favourably from AqET or TPT programs. The AqET is more beneficial than the TPT in increasing the PF and the aquatic skills performance in older children with spastic CP.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Stavsky M, Mor O, Mastrolia SA, Greenbaum S, Than NG, Erez O. Cerebral palsy-trends in epidemiology and recent development in prenatal mechanisms of disease, treatment, and prevention. Front Pediatr. 2017;5:21; doi: 10.3389/fped.2017.00021.
2. Patel DR, Neelakantan M, Pandher K, Merrick J. Cerebral palsy in children: a clinical overview. Transl Pediatr. 2020;9(Suppl 1):125–135; doi:10.21037/tp.2020.01.01
3. Jones MW, Morgan E, Shelton JE, Thorogood C. Cerebral palsy: introduction and diagnosis (part I). J Pediatr Health Care. 2007;21(3):146–152; doi: 10.1016/j.pedhc.2006.06.007.
4. Himmelmann K, Hagberg G, Uvebrant P. The changing panorama of cerebral palsy in Sweden. X. Prevalence and origin in the birth-year period 1999–2002. Acta Paediatr. 2010;99(9):1337–1343;doi:10.1111/j.1651-2227.2010.01819.x.
5. Nsenga AL, Shephard RJ, Ahmaidi S. Aerobic training in children with cerebral palsy. Int J Sports Med. 2013;34(6):533–537; doi: 10.1055/s-0032-1321803. Erratum in: Int J Sports Med. 2013;34(7):667. Ahmadi S [corrected to Ahmaidi S].
6. Ersöz M, Selçuk B, Gündüz R, Kurtaran A, Akyüz M. Decreased chest mobility in children with spastic cerebral palsy. Turk J Pediatr. 2006;48(4):344–350.
7. Lampe R, Blumenstein T, Turova V, Alves-Pinto A. Lung vital capacity and oxygen saturation in adults with cerebral palsy. Patient Prefer Adherence. 2014;8:1691–1697; doi: 10.2147/PPA.S72575.
8. Young NL, McCormick AM, Gilbert T, Ayling-Campos A, Burke T, Fehlings D, Wedge J. Reasons for hospital admissions among youth and young adults with cerebral palsy. Arch Phys Med Rehabil. 2011;92(1):46–50; doi: 10.1016/j.apmr.2010.10.002.
9. Elema A, Zalmstra TA, Boonstra AM, Narayanan UG, Reinders-Messelink HA, Putten AAJVD. Pain and hospital admissions are important factors associated with quality of life in nonambulatory children. Acta Paediatr. 2016;105(9):419–425; doi: 10.1111/apa.13493.
10. Blair E, Langdon K, McIntyre S, Lawrence D, Watson L. Survival and mortality in cerebral palsy: observations to the sixth decade from a data linkage study of a total population register and National Death Index. BMC Neurol. 2019;4:19(1):111–121; doi: 10.1186/s12883-019-1343-1.
11. Himmelmann K, Sundh V. Survival with cerebral palsy over five decades in western Sweden. Dev Med Child Neurol. 2015;57(8):762–767; doi: 10.1111/dmcn.12718.
12. Proesmans M. Respiratory illness in children with disability: a serious problem? Breathe. 2016;12(4):97–103; doi: 10.1183/20734735.017416.
13. Kwon YH, Lee HY. Differences of respiratory function according to level of the gross motor function classification system in children with cerebral palsy. J Phys Ther Sci. 2014;26(3):389–391; doi:10.1589/jpts.26.389.
14. Seddon PC, Khan Y. Respiratory problems in children with neurological impairment. Arch Dis Child. 2003;88(1):75–78; doi: 10.1136/adc.88.1.75.
15. Getz M, Hutzler Y, Vermeer A, Yarom Y, Unnithan V. 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. Int Scholarly Res Notices. 2012;2012:8; doi: 10.5402/2012/657979.
16. Adar S, Dündar Ü, Demirdal ÜS, Ulaşlı AM, Toktaş H, Solak Ö. The effect of aquatic exercise on spasticity, quality of life, and motor function in cerebral palsy. Turk J

Phys Med Rehabil. 2017;63(3):239–248; doi:10.5606/tftrd.2017.280.
17. 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(4):336–344; doi: 10.1097/pep.0b013e3181beb039.
18. Ballaz L, Plamondon S, Lemay M. Group aquatic training improves gait efficiency in adolescents with cerebral palsy. Disabil Rehabil. 2011;33(17–18):1616–1624; doi: 10.3109/09638288.2010.541544.
19. Tufekcioglu E, Konukman F, Kaya F, Arslan D, Ozan G, Erzeybek MS, et al. The effects of aquatic Watsu therapy on gross motor performance and quality of life for children with cerebral palsy. Monten J Sports Sci Med. 2021;10(2):25–30; doi: 10.26773/mjssm.210904.
20. Sutthibuta U. Systematic review of aquatic exercise programming for children and adolescents with cerebral palsy. Int J Child Develop Mental Health. 2014;2(1):49–66.
21. Declerck M, Feys H, Daly D. Benefits of swimming for children with cerebral. Palsy pilot study. Serb J Sports Sci. 2013;7(2):57–69.
22. Palisano RJ, Rosenbaum P, Bartlett D, Livingston MH. Content validity of the expanded and revised Gross Motor Function Classification System. Dev Med Child Neurol. 2008;50(10):744–750; doi: 10.1111/j.1469-8749.2008.03089.x.
23. Kwon H-Y. Comparison of differences in respiratory function and pressure as a predominant abnormal movement of children with cerebral palsy. J Phys Ther Sci. 2017;29(2):261–265; doi: 10.1589/jpts.29.261.
24. Tirosh R, Katz-Leurer M, Getz MD. Halliwick-based aquatic assessments: reliability and validity. Int J Aquatic Res Educ. 2008;2(3):224–236; doi: 10.25035/ijare.02.03.04.
25. Dimitrijević L, Aleksandrović M, Madić D, Okičić T, Radovanović D, Daly D. The effect of aquatic intervention on the gross motor function and aquatic skills in children with cerebral palsy. J Hum Kinet. 2012;32:167–174; doi: 10.2478/v10078-012-0033-5.
26. 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(2):69–78; doi: 10.3109/09593985.2013.825825.
27. Atia DT, Tharwat MM. Effect of incentive spirometer exercise combined with physical therapy on pulmonary functions in children with cerebral palsy. Int J Ther Rehabil. 2021;28(1):1–8; doi: 10.12968/ ijtr.2020.0072.
28. Epstein LH, Paluch RA, Kalakanis LE, Goldfield GS, Cerny FJ, Roemmich JN. How much activity do youth get? A quantitative review of heart-rate measured activity. Pediatrics. 2001;108(3):E44; doi: 10.1542/peds.108.3.e44.
29. Petersen TM. Pediatric Aquatic Therapy. In: Cole AJ, Becker BE (ed.), Comprehensive Aquatic Therapy. Philadelphia: Elsevier; 2004:239–288.
30. Prins JH. Aquatic rehabilitation. Serb J Sports Sci. 2009; 3(1-4):45–51.
31. Lee HY, Cha YJ, Kim K. The effect of feedback respiratory training on pulmonary function of children with cerebral palsy: a randomized controlled preliminary report. Clin Rehabil. 2014;28(10):965–971; doi: 10.1177/0269215513494876.
32. Park ES, Park JH, Rha D-W, Park CI, Park CW. Comparison of the ratio of upper to lower chest wall in children with spastic quadriplegic cerebral palsy and normally developed children. Yonsei Med J. 2006;47(2):237–242; doi: 10.3349/ymj.2006.47.2.237.
33. Lai C-J, Liu W-Y, Yang T-F, Chen C-L, Wu C-Y, Chan R-C. Pediatric aquatic therapy on motor function and enjoyment in children diagnosed with cerebral palsy of various motor severities. J Child Neurol. 2015;30(2):200–208; doi: 10.1177/0883073814535491.
34. 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; doi: 10.1155/2011/712165.
35. Kesiktas N, Paker N, Erdogan N, Gülsen G, Biçki D, Yilmaz H. The use of hydrotherapy for the management of spasticity. Neurorehabil Neural Repair. 2004;18(4):268–273; doi: 10.1177/1545968304270002.
36. Thorpe DE, Reilly M, Case L. The effects of an aquatic resistive exercise program on ambulatory children with cerebral palsy. J Aquatic Phys Ther. 2005;13(2):21–34.
37. Brunton LK, Rice CL. Fatigue in cerebral palsy: a critical review. Dev Neurorehabil. 2012;15(1):54–62; doi: 10.3109/17518423.2011.629633.
38. Jorgić B, Dimitrijević L, Aleksandrović M, Okičić, T, Madić DM, Radovanović D. The swimming program effects on the gross motor function, mental adjustment to the aquatic environment, and swimming skills in children with cerebral palsy: a pilot study. Spec Educ Rehabil. 2012; 11(1):51–66; doi: 10.5937/specedreh1201051J.
39. Valle M, Vo A, Liu H, Salem Y. Effectiveness of aquatic therapy interventions in the management of children with cerebral palsy: a systematic review. Dev Med Child Neurol. 2017;59(S3):107–108; doi: 10.1111/dmcn.47_13512.
40. Getz M, Hutzler Y, Vermeer A. Effects of aquatic interventions in children with neuromotor impairments: a systematic review of the literature. Clin Rehabil. 2006;20(11):927–936; doi: 10.1177/0269215506070693.