Effects of aquatic therapy practices on range of motion in children with cerebral palsy

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Abstract:

The purpose of the present study was to examine the effects of aquatic therapy practices range of motion in cerebral palsy children. Twenty children 7-12 years old with cerebral palsy were selected by a convenience sampling method. Participants were placed in experimental and control groups. The experimental group performed aquatic therapy practice in water for 8 weeks, but the control group continued their traditional program. Universal goniometer were used as instruments. Multivariate analysis of covariance (MANCOVA) and Analyze of Covariance (ANCOVA) were used at $p < 0.05$ level. Based on MACNOVA test results, there was a significant difference between experimental and control groups at least in one dependent variable (shoulder, elbow, & wrist range of motion) ($F = 28/050$, $p= 0/000$). Based on the results of ANCOVA test, experimental group achieved higher averages in shoulder, elbow and wrist range of motion than control group. Aquatic therapy practices can be used as a treatment approach for improving upper extremity range of motion in children with hemiplegic cerebral Palsy.

Keywords:

Hemiplegic cerebral palsy, range of motion, aquatic therapy

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1. Introduction

Cerebral palsy is a non-progressive lesion to the developing brain that causes one of the most prevalent chronic motor disabilities and neurological disorders in children. This lesion could develop before, during, or after birth and is commonly associated with sensory, perceptual,

cognitive, communicative, and behavioral disorders, as well as epilepsy and musculoskeletal issues, limiting activities and reducing participation in social activities (20). Cerebral palsy affects at least 2 out of every 1000 children. Children with cerebral palsy comprise a substantial part of this group. In recent years, this statistic for Iran has been around 2.6 per 1000 children born, and premature newborns and multiple twins are more prone to it (10). Cerebral palsy is a physical injury that can occur in children due to traumatic brain injury to the growing brain, strokes, or brain tumors. Approximately one-third of children with cerebral palsy have spastic hemiplegia, a debilitating symptom of cerebral palsy that causes a unilateral loss of hand and arm function. Sensory and motor deficits continually influence children's motor adequacy. These children are frequently hesitant to use the injured side, aggravating the injury and leading to the lack of intellectual development in the upper limb on the affected side (4). Among the common problems associated with cerebral palsy are poor depth perception, abnormal contact perception, altered sensitivity to pain, and also increased pain and abnormal activity of the somatosensory areas of the cerebral cortex, as well as decreased range of motion and connective tissue stiffness, are all somatosensory changes in hemiplegic cerebral palsy (21). Cerebral palsy is associated with several secondary disorders that may have a more significant impact on the children and their families than cerebral palsy (19) and affect all aspects of a child's development throughout their life.

Cerebral palsy causes upper extremity dysfunction, which leads to issues reaching, pointing, grabbing, dropping, and kneading objects. The most prevalent type of cerebral palsy is spastic cerebral palsy, where muscular imbalance and poor movement control affect a child's ability to perform daily activities. Approximately half of all children with cerebral palsy suffer from dysfunction. Disorders in various motor functions of children with cerebral palsy reduce the working capacity of the upper limbs, weight-bearing and transfer parts of the lower limbs, and limit static and dynamic spinal functions, which ultimately leads to the limitation of environmental capabilities and their social adaptation. On the other hand, neurological disorders, including spasms, the concurrent activity of agonist and antagonist muscles, muscle weakness, and the range of motion limitations, influence the gross and fine motor function of children with cerebral palsy, resulting in movement limitations (3). The scope of self-care in daily life in children with cerebral palsy is related to their fine motor function in their hands (16) hand function evaluation over time and after therapy should concentrate on the actual use of the

injured hand in daily activities. Range of motion of the upper limbs is an essential issue in a patient's rehabilitation process because it provides objective and helpful information in the diagnosis and clinical follow-up of the physical condition progress (11). When the hand's range of motion is reduced, compensatory movements of the trunk and other upper-limb joints (shoulder, elbow, and forearm) are increased (1). According to Bortner, spasticity in these children causes abnormal movement patterns with the upper limb in the position of internal rotation of the shoulder, elbow flexion, forearm pronation, ulna deviation, wrist flexion, and other deformities in their fingers. Eighty percent of children with hemiplegia have functional limitations in their upper limbs (5).

Different methods of intervention were used in therapy programs of children with CP. For example, Chang et al (6) evaluated the effects of virtual reality (VR)-based rehabilitation combined with conventional occupational therapy (COT) on upper extremity function among children with CP. They suggested that VR-based rehabilitation combined with conventional occupational therapy (COT) might improve the upper extremity functions among children with CP. Mittag et al (18) investigated the development of a home-based wrist range-of-motion training system for children with cerebral palsy. Also, Kalkman et al (14) discussed how muscle and tendon interact based on their morphology and mechanical properties to provide a certain range of motion at the joint. Furthermore, methods such as water exercises had positive impact on the motor and physical performance of children with cerebral palsy (13). In fact, activity for these people can have a therapeutic and preventive effect on the problems of disability and be fun and entertaining. Water exercise has been examined for its influence on various facets of life in different sections of society. Hydrotherapy, for example, improves the quality of life, neuromuscular function, and balance (7). For ages, water treatment has been utilized as a scientifically approved technique in medicine. Water treatment dates back to ancient Greece and Rome, and China. The use of water in medicine became widespread in the 18th century, and the word "hydrotherapy" was coined. The first hydrotherapy office opened in Europe in the 19th century, accelerating the healing, alleviation, and even eradication of muscle and joint pain and treating physical disabilities. It was utilized to speed up bone healing, strengthen muscles, activate inactive muscles, improve blood circulation in the arteries, and even relieve people with a mental health condition. Water's miraculous characteristics (health and healing dimensions) have long been apparent and with the advancement of different sciences, including, of course,

the science of physical education and sports, water sports training programs are now being considered. Performing physical activities is demanding in terms of pressure. Individuals do not want to do them, but exercising in water relieves joint pressure and gives them a sense of being underweight. Formal hydrotherapy does the same, so when compared to ground sports, it is one of the ineffective sports since the pressure on the joints is substantially reduced

Hydrotherapy has been widely utilized in recent years to enhance the degree of physical fitness and rehabilitation of persons with disabilities, eliminate disease symptoms, and improve motor and cognitive abilities in many diseases. Hydrotherapy improves the motor-sensory function of healthy and disabled individuals because it is a valuable and cost-effective way of managing symptoms such as pain, muscle spasm, dysfunction, and imbalance (12). The results of a study by Alder et al. (2) examined water activities in 21 children with severe cerebral palsy and the relation among the process of teaching and learning and evaluating these children's social performance. The results showed evident improvement in the children's social functioning in the water training group. Overall, the findings of this study demonstrated that physical water exercises help children with cerebral palsy improve their motor development, social function, and independence. In a review study (9) examined the effects of water exercise on children and adults with cerebral palsy. According to the findings of this study, water exercise has an excellent therapeutic effect on people with cerebral palsy. The procedure demonstrates an improvement in movement limitations (17) also examine the impact of water exercises on gross body movement and water skills in children with cerebral palsy. The study included 29 children with cerebral palsy, 14 of whom participated in water exercises and 13 in the control group. Water exercises are held twice a week for six weeks, with each session lasting 55 minutes. A memory test was conducted three weeks following the end of the exercises. The results of this study revealed that water exercises have a substantial impact on the development of gross body movements and water skills in these children.

In contrast to the improvement in water skills, there were no significant changes in gross motor skills during the follow-up period. According to the findings of this study, children with cerebral palsy can enhance their gross motor development. In a study on the effects of hydrotherapy on motor function in children with cerebral palsy with varying degrees of movement limitation, chih jou Lai et al. (8) found that this sort of exercise is beneficial to children with cerebral palsy.

This study aimed to investigate the effects of a hydrotherapy exercise program on the range of motion of the shoulder, elbow, and wrist joints, considering the above contradictory findings as well as limited research on the effects of hydrotherapy on the function of children with cerebral palsy. In this study, we hypothesized that water-based exercise improves performance indicators in these children.

2. Methodology

Children with cerebral palsy aged 7 to 12 years in Tehran were included in the statistical population of the present study, which comprised 1575 people studying in the academic year 1397-1398. The study's statistical sample included 20 boys with spastic cerebral palsy who were chosen based on available sampling due to the original study's limited number. Children with cerebral palsy aged 7 to 12 years in Tehran were included in the present study's statistical population, totaling 1575 people studying in the academic year 1397-1398. The study's statistical sample included 20 boys with spastic cerebral palsy who were chosen based on available sampling due to the original study's limited number.

Entry criteria for children with cerebral palsy were: 1- Gender (in this study, boys), 2- Spastic hemiplegia cerebral palsy, 3- No mental disabilities, and 4- Age (between 7 and 12). Additionally, the output criteria include: 1- having neurodegenerative diseases, 2- having severe spasticity (modified Ashworth scale score +4). 3- Head injuries 4- hearing and vision impairment 5- moderate to severe mental disability 6- A history of botulinum, alcohol, or phenolic acid injections into the upper limbs. 7- Epilepsy. The subjects' range of motion was measured and recorded using a standard universal goniometer in this study.

Three repetitions were performed in each upper limb joint (shoulder, elbow, and wrist), and the mean was chosen as the joint's range of motion. The researcher measured the inactive range of motion of the shoulder, elbow, and wrist joints in flexion and extension motions since children with cerebral palsy frequently have a reduced range of motion in the upper extremity joints (15). Within the tester ($r = 0.91$) and among testers ($r = 0.91$) high goniometer reliability was reported (25). All range of motion measurements of the shoulder, elbow, and wrist were taken by one individual at a specific time of day, on bare skin, with an instrument in a similar position.

Figure 1. View of the universal goniometer

The parents or guardians of the study participants were initially asked to sign a consent document. Pre-test measurements of the shoulder, elbow, and wrist joints range of motion were taken, and the subjects were homogeneously split into experimental and control groups based on the mean range of motion. The instructor conducted water exercises for ten children in the experimental group at certain intervals during the training phase. The subjects in this group then performed water exercises for eight weeks (3 days per week for 1 hour and 15 minutes each the day). Each session began with a warm-up that included water walking and static stretching exercises. After that, upper-limb exercises are done, which include 1- Shoulder flexion, 2- Shoulder extension, 3- Shoulder abduction, 4- Shoulder adduction, 5- Elbow flexion, 6- Elbow extension, 7- Flexion of the wrist, 8- Wrist extension in slow motion with 50% of maximum heart rate with ten repetitions and at the end of light stretching movements and water play. The control group did not participate in any water exercises and merely followed their regular treatment routine prior to entering the study, except for evaluation sessions. All training and testing took place in a calm atmosphere over a specific length of time. The subjects from both groups (experimental and control) returned to the laboratory at the end of the training session and the parameters relating to the shoulder, elbow, and wrist joints range of motion were re-evaluated.

The central indices and dispersion related to the sizes of experimental groups were estimated in the descriptive statistics section. The Shapiro Wilkes test was used in inferential statistics to determine the normal data distribution. The researcher employed multivariate analysis of covariance (MANCOVA) and univariate analysis of covariance (ANCOVA). For all variables,

the significance level was considered $p<0.05$. SPSS 20 software was used for all statistical analyses. The graphs were drawn by Excel software.

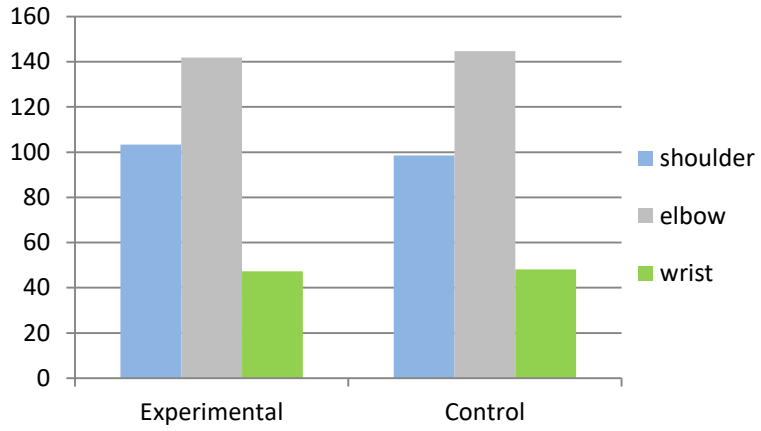
3. Findings

In this section, the demographic indicators of the experimental and control group subjects are illustrated in Table 1.

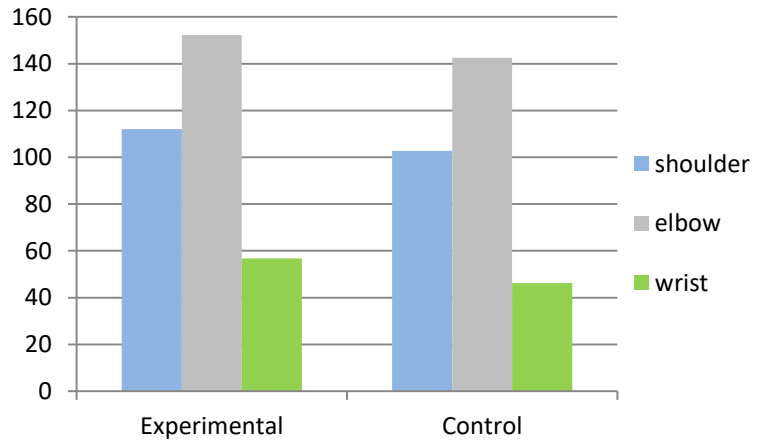
Table 1 . Participant demographics

Variables	Goups	Mean	SD	t	sig
Age	Experimental	9.70	1.41	-0.64	0.954
	Control	10.10	1.37		
Height	Experimental	117.80	1.75	2.25	0.349
	Control	116.20	2.88		
Weight	Experimental	25.60	1.71	1.41	0.25
	Control	24.10	2.88		

Based on the results of an independent t-test, the demographic indicators of age, height, and weight of children with hemiplegic cerebral palsy in the experimental and control groups did not significantly differ. Figure 1 illustrates the mean range of motion scores for the shoulder, elbow, and wrist in children with cerebral palsy at the pre-test and post-test stages. Furthermore, neither the Leven test nor the Shapiro-Wilkes test statistics was significant in any of the studied variables (p 0.05), indicating the homogeneity of variances and normal distribution of the pre-test data of the studied variables, respectively. In addition, the homogeneity of the variance/covariance matrices is one of the assumptions of multivariate analysis of statistical variance test. In the post-test stage, the M-box tests indicated that the covariance matrices between dependent variables were equal ($p = 0.09$).



Pre-test



Post-test

Figure 2. Mean scores related to shoulder, elbow, and wrist range of motion in pre-test and post-test stages

Table 2. MANCOA test results

effect	value	Hypothesis df	Error df	F	Sig	Patial Eta Squared	Statistical power
Pillai's Trace	0.866	3	13	28.050	0.000	0.866	1.00
Wilks' Lambda	0.134	3	13	28.050	0.000	0.866	1.00
Hotelling's Trace	6.471	3	13	28.050	0.000	0.866	1.00
Roy's Largest Root	6473.07	3	13	28.050	0.000	0.866	1.00

As shown in Table 2, significant levels with pre-test control suggest that at least one of the dependent variables between children with cerebral palsy in the experimental and control groups (shoulder range of motion, range of motion of the elbow, wrist range of motion) is significantly different (p = 0.000, F = 28.050). Three one-way covariance analyses were performed in MANCOVA text to determine which variable has a significant difference between the two groups, with the results illustrated in Table 3.

Table 3. Results of one-way covariance test

Dependent Variable	Source	Type III Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared	Statistical power
Shoulder	group	111.788	1	111.788	50.161	.000	.770	1.00
	Error	33.429	15	2.229				
	Corrected Total	234434.0	20					
elbow	group	51.079	1	51.079	39.475	.000	.725	1.00
	Error	19.410	15	1.294				
	Corrected	437670. 0	20					

	Total							
wrist	group	70.035	1	70.035	69.633	.000	.823	1.00
	Error	15.087	15	1.294				
	Corrected Total	55678. 0	20					

As shown in Table 3, there was a significant difference in shoulder range of motion (p = 0.000, F = 50.161), elbow range of motion (p = 0.000, F = 475.395), and wrist range of motion (p = 0.000, F = 69.633) when the pretest was controlled. Children with cerebral palsy were divided into experimental and control groups. In other words, virtual reality exercises enhanced the shoulder range of motion, elbow, and wrist joints of children with cerebral palsy compared to the control group since the experimental group's mean range of motion was higher.

4. Discussion and Conclusion

More than half of children with hemiplegia have functional disorders of the arm and hand, which are one of the leading causes of inability to perform daily activities (22). Researches showed that can be determined with sufficient accuracy to control a game in children with CP (18). Recently, water sports have been widely used to enhance people with disabilities' level of physical fitness and rehabilitation. Hydrotherapy and water exercise are one of these ways that has had increasing popularity in the last two decades due to its benefits and has evolved into a type of exercise therapy. Hydrotherapy can be helpful in the relief of the disease symptoms as well as the improvement of motor and cognitive abilities in a variety of diseases. It is used to improve the motor-sensory function of healthy and disabled individuals because it is a useful and cost-effective method of controlling symptoms such as pain, muscle spasm, dysfunction, and imbalance (12). Research findings of previous studies have demonstrated that following a period of hydrotherapy exercises improves movement limitations in children with cerebral palsy. For instance, in a study, Alder et al. (2) reviewed water activities in people with severe cerebral palsy and those activities relationship to the learning process. The study was conducted because the number of children with cerebral palsy has increased over the last decade. Cerebral palsy has a

destructive effect on a person's nervous system, causing constant sensory-motor, muscular tension, position, and voluntary movements problems. The results of this study generally demonstrated that physical water exercises could remarkably help children with cerebral palsy improve their motor development. In a review article, (9) examined the effects of water exercise on children and adults with cerebral palsy. The research results indicate that this method is effective in improving mobility limitations, as the participants in this study made substantial progress in overcoming these limits. In a study, Lydia et al. (17) examined how water exercises affected the performance of gross body movements and water skills in children with cerebral palsy.

The findings of this study revealed that water exercises have a major impact on these children's development of gross body movements and water skills. The present study's findings demonstrated that water exercises significantly improve the shoulder, elbow, and wrist joint range of motion in children with cerebral palsy. In addition, its findings are consistent with those of Alder et al. (2), corter and Kerry (9), Lydia et al. (17), Chi Lou et al. (8). for instance, conducted a study titled “The Effect of Hydrotherapy on Some Selected Parameters Related to Kyphosis in Kyphotic Girls.” According to their findings, hydrotherapy increased the motion of shoulder abduction range compared to pre-workout values.

Furthermore, based on the findings of some studies, the range of motion of children with cerebral palsy improves due to enhanced muscle group ability. In a study conducted in province, Daniar 2015 examined the effect of 8 weeks of progressive resistance training on the physical and motor condition of children with hemiplegic cerebral palsy. According to the results of this study, conducting progressive resistance exercises improves motor function and increases the isometric hand strength of children with hemiplegic cerebral palsy. In a study titled “Muscle Stiffness and Strength and Their relation to Hand Function in Children with Spastic Hemiplegic”, demonstrated that there is a significant relationship between the range of motion, stiffness, and muscle weakness with hand function in children with cerebral palsy. The study results can also be interpreted as an indication that children with cerebral palsy have a higher level of activity and require the use of more muscle groups due to their higher tendency to perform activities in water environments. Furthermore, it appears that water resistance and its effect on the movement perception as well as the subsequent strengthening of the individuals' muscles were not ineffective.

Furthermore, water environments' stimulating and appealing characteristics can motivate children with cerebral palsy to participate and continue exercising as much as possible. For instance, Chih Lu et al. (8) examined the effects of hydrotherapy on motor function and pleasure in children with cerebral palsy who had various degrees of motor limitation. For instance, Chi Lu et al. (8) examined the effects of hydrotherapy on motor function and pleasure in children with cerebral palsy who had various degrees of motor limitation. This study examined the impact of hydrotherapy on motor function, daily activities, and health-related quality in children with spastic cerebral palsy and different motor limitations. The results of this study demonstrated that following a period of hydrotherapy, the gross motor function of children with spastic cerebral palsy improved, and their mean motor function rised when compared to the control group. Also, with the help of the physical activity enjoyment questionnaire, it became clear that the group who did water activities had more fun. Based on the results of this study, hydrotherapy can be a successful and different treatment for children with cerebral palsy. In the present study, children with cerebral palsy were able to undertake water exercises in an enjoyable atmosphere where their propensity to do a high-level activity was reported.

After reviewing previous research, the researcher found no research indicating that water exercise did not improve range of motion. For example, studied the effect of land and water exercise therapy on the range of knee motion in hemophilia patients. They discovered that both land and water exercise therapy enhanced the knee joint range of motion in hemophilia patients; however, there was no meaningful significance between them. Based on dynamic systems theory, the basic motor abilities are not entirely determined by heredity, and basic enrichment impacts subsequent growth. In this type of model, task factors, individuals, and the environment interact with one another. Also, they can make changes or change with increasing motor control and motor adequacy.

Often, various factors can influence the results of the research and make the results stronger or weaker than reported, the most critical of which include lack of precise control of motivation, desire, and fatigue in performing the test, lack of precise control of maturity, physical ability and level of physical activity of the subjects as well as hereditary characteristics, individual differences, and behavioral characteristics of the individual and their parents Increasing tendon stiffness to enhance the stretching stimulus seems to be a potentially promising strategy after training, as Kalkman et al. (15) found increases in fascicle lengths after ROM intervention.

Finally, the World Health Organization recommends at least 60 minutes of moderate to vigorous physical activity each day for children with and without disorders to avoid the dangers of inactivity and to enjoy the benefits of physical activity. The present study's exercise program is recommended to children with cerebral palsy since it can improve their performance and basic skills. According to the findings of this study, swimming exercises are stressed as a series of exercises that are welcomed and motivated for children with cerebral palsy to engage in physical activity. Given the results of this study and the motivational effect of water exercise, a similar study in a statistical population of children with various physical disorders is recommended.

5. Reference

1. Adams, B.D., Grosland, N.M., Murphy, D.M., Mc Cullough, M., & City, I. (2003). Impact of impaired wrist motionon hand and upper-extremity performance .J Hand Surg, 28: 898–903.

2. Alder F J. Silva A J. Machado RELS V. Carneiro Ander L. et al (2007). Aquatic activities for severe cerebral palsy people and relation with the teach-learning process. Journal fitness performance. 1676-5133. doi:10.3900/fpj.6.6.377 .

3. Bax, M., et al. (2005). Proposed definition and classification of cerebral palsy, April 2005. Developmental Medicine & Child Neurology, vol. null, no. 8, pp.571-576. ISSN 1469-8749.

4. Brady K, Garcia T. Constraint- induced movement therapy(CIMT): Pediatric Applications,J Developmental Disabilitities2009; 15: 102-111.

5. Burtner, P.A, Pool, J.A, & Torres, T. (2008). Effects of wrist hand splints on grip, pinch, manual dexterity and muscle activation in children with spastic hemiplegia. J Hand Ther, 21:36-43.

6. Chang HJ, Ku KH, Park YS, Park JG, Cho ES, Seo JS, Kim CW, O SH. Effects of Virtual Reality-Based Rehabilitation on Upper Extremity Function among Children with Cerebral Palsy. Healthcare (Basel). 2020 Oct 10;8(4):391. doi: 10.3390/healthcare8040391. PMID: 33050396; PMCID: PMC7711757.

7. Chen.Y, Kang.L, Chuang.T, Doong J, Lee S, Tsaei M and et al. Use of virtual reality to improve upper-extremity control in children With cerebral palsy. Physical Therapy.2007; 87; 1441-1457.

8. Chih-Jou lai. Wen-Yu Liu, Tsui-Fen Yang, Chia-Ling Chen, Ching-Yi Wu, ScD, OTR, Rai-Chi Chan, (2014). Pediatric Aquatic Therapy on Motor Function and Enjoyment in Children Diagnosed With Cerebral Palsy of Various Motor Severities. Journal of Child Neurology. 1-9. DOI: 10.1177/0883073814535491

9. Corter j.w. Currie s j. (2011). Aquatic Exercise Programs for Children and Adolescents with Cerebral Palsy:What DoWe Know andWhere DoWe Go? International Journal of Pediatrics. 712165, 7 pages. doi:10.1155/2011/712165.

10. Dalvand H, Dehghan L, Hadian MR, Feizy A, Hosseini SA. Relationship between gross motor and intellectual function in children with cerebral palsy: across sectional study. Archives of PhysicalMedicine and Rehabilitation. 2012, [cited 2013 Mar 5]

11. Francisco-Martínez C, Prado-Olivarez J, Padilla-Medina JA, Díaz-Carmona J, Pérez-Pinal FJ, Barranco-Gutiérrez AI, Martínez-Nolasco JJ. Upper Limb Movement Measurement Systems for Cerebral Palsy: A Systematic Literature Review. Sensors (Basel). 2021 Nov 26;21(23):7884. doi: 10.3390/s21237884. PMID: 34883885; PMCID: PMC8659477.

12. Hayden JA, van Tulder MW, Malmivaara AV, Koes BW (2005). Meta-analysis: exercise therapy for nonspecific low back pain. Ann Intern Med. 142(9): 765-75.

13. Hurvitz EA, Leonard C, Ayyanger R, Nelson VS, Complementary and alternative use in families of children with cerebral palsy. Dev Med child Neurol 2003: 45(6): 364-70.)

14. Kalkman BM, Bar-On L, O'Brien TD, Maganaris CN. Stretching Interventions in Children With Cerebral Palsy: Why Are They Ineffective in Improving Muscle Function and How Can We Better Their Outcome? Front Physiol. 2020 Feb 21;11:131. doi: 10.3389/fphys.2020.00131. PMID: 32153428; PMCID: PMC7047287.

15. Kalkman, B. M., Holmes, G., Bar-On, L., Maganaris, C. N., Barton, G. J., Bass, A., et al. (2019). Resistance training combined with stretching increases tendon stiffness and is more effective than stretching alone in children with cerebral palsy: a randomized controlled trial. Front. Pediatr. 7:333. doi: 10.3389/fped. 2019.00333.

16. Kwon, T., et al. (2018). Relationship Between Gross Motor Function and Daily Functional Skill in Children With Cerebral Palsy. Annals of rehabilitation medicine, vol. 37, no. 1, pp.41-49. ISSN 2234-0645.

17. Lidija D. Marko A. Dejan M. Tomislav O. Dragan R. Daniel D. (2012). The Effect of Aquatic Intervention on the Gross Motor Function and Aquatic Skills in Children with Cerebral Palsy. Journal of Human Kinetics volume 32: 167-174.

18. Mittag, Christina, Leiss, Regina, Lorenz, Katharina and Seel, Thomas. "Development of a home-based wrist range-of-motion training system for children with cerebral palsy" at - Automatisierungstechnik, vol. 68, no. 11, 2020, pp. 967-977. https://doi.org/10.1515/auto-2020-0085

19. Pellegrino L, Batshaw ML, Roizen NJ. Cerebral palsyin children with disabilities. 6th ed. Baltimore (MD): Paul H. Brookes Publishing Co.; 2007.

20. Prudente COM, Barbosa MA, Porto CC.(2010) Relation between quality of life of mothers of children with cerebral palsy and the children's motor functioning, after ten months of rehabilitation.

21. Riquelme, I., et al. (2014). Differences in somatosensory processing due to dominant hemispheric motor impairment in cerebral palsy. BMC neuroscience, 15, 1, pp: 10.

22. Wesdock, K.A., Kott, K., Sharps, C. (2008). Pre- and post-surgical evaluation of hand function in hemiplegic cerebral palsy. J Hand Ther, 21:386-97.