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Miriam Getz, Yeshayahu Hutzler and Adri Vermeer

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Effects of aquatic interventions in children with neuromotor impairments: a systematic review of the literature

Miriam Getz The Kibuzzim College of Education and Dance, Tel Aviv, and the Israel Sport Center for the Disabled in Ramat Gan, **Yeshayahu Hutzler** The Zinman College for Physical Education and Sports at the Wingate Institute and the Israel Sport Center for the Disabled in Ramat Gan, Israel and **Adri Vermeer** The Faculty of Educational Sciences of the Utrecht University, The Netherlands

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Objective: To determine the effectiveness of aquatic interventions in children with neuromotor impairments.
Design: A search of electronic databases that included MEDLINE, PubMed, ERIC, PsychLit, PEDro, Sport Discus, CINAHL and Cochrane between 1966 and January 2005 was conducted using the following keywords: 'hydrotherapy', 'aquatic therapy', 'water exercise', 'aquatics', 'adapted aquatics', 'aquatic exercise' and 'swimming'. An additional resource, the Aquatic Therapy Research Bibliography until 1999, was explored manually. Titles and abstracts were assessed manually according to the following inclusion criteria: (1) population (children with neuromotor or neuromuscular impairments), (2) intervention (aquatic programme). Articles were reviewed according to merit of design, population participants and outcome measures with respect to International Classification of Function and Disability terminology (changes in body function, activity level and participation).
Results: Eleven of the 173 articles that were retrieved met the inclusion criteria: one randomized control trial, two quasi-experimental studies, one cohort study, two case control studies and five case reports. Seven articles reported improvement in body functions, and seven articles reported improvement in activity level. Two of the four articles that investigated outcome measures regarding participation described positive effects while the findings of the other two revealed no change. None of the articles reported negative effects due to aquatic interventions.
Conclusion: According to this review, there is a substantial lack of evidence-based research evaluating the specific effects of aquatic interventions in this population.

Introduction

Swimming and hydrotherapy have been viewed as beneficial activities for children with neuromotor impairments.[1–5] They provide an opportunity to improve physiological and psychological achievements. Aquatic activity exercises the total body without putting excessive stress or tension on specific body parts.[3,5] The warm aquatic environment of 32–33°C reduces muscle tone, which in turn allows more efficient movement for children with high muscle tone.[1] An additional therapeutic quality of water is buoyancy, which enables initiation of independent

Address for correspondence: Miriam Getz, The Kibbutzim College for Education and Dance, Derech Namir 149 Ramat Aviv, Israel. e-mail: miri_get@smkb.ac.il

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movement possibilities that are less likely to be achieved on land.[2,6,7]

Aquatic interventions are one of the most popular types of alternative therapies in treating children with cerebral palsy and related neuromotor impairments.[8] Despite this popularity, little research has been documented which establishes specific outcome effects.[9] Like other therapeutic methods practised in neuropaediatric treatment, the main goal of aquatic therapy is to improve daily living activities and enhance body functions. Evidence-based research is the preferred method for better guaranteeing clinical decisions regarding a child's care.

The majority of research on aquatic intervention focuses on the adult population.[10,11] Dumas and Francesconi[12] published a review of aquatic therapy intervention in paediatrics. Although the review described details of current research, it concentrated more on the content of the studies rather than addressing assessment of methodological quality and reliability of outcome measures.

Current disability research[13] should measure components included in the widely accepted International Classification of Function and Disability (ICF)[14] The ICF suggests that the individual should be observed in a multidimensional context so that assessment and treatment goals can be determined not only from a medical perspective, but from a social-ecological perspective. Individual function and disability are represented by three dimensions: (a) body structure and function, (b) activity and (c) participation. These three dimensions interact with personal and environmental contextual factors.

The purpose of this review is to evaluate the effectiveness of aquatic interventions in children with neuromotor impairments with regard to the ICF dimensions and level of scientific evidence.

Method

An online computer search of electronic databases going back to the earliest available time (1966) was established. The accessed databases included MEDLINE, PubMed, Educational Resources Information Center (ERIC), PsychINFO, PEDro–Physiotherapy Evidence Database, Sport Information Resource Center (SIRC), Cumulative Index to Nursing and Allied Health Literature (CINAHL) and Collaboration Register Database (Cochrane). In addition, the Aquatic Therapy Research Bibliography (until 1999) was explored manually. Databases were searched using the following keywords: 'hydrotherapy',' aquatic therapy', 'water exercise', 'aquatics', 'adapted aquatics', 'aquatic exercise' and 'swimming'. Searches covered literature from 1966 through January 2005. The search was limited to journal articles written in English, research, and research populations from 0 to 18 years of age.

Titles and abstracts extracted form the database search were read by two independent reviewers and were included if they met the following criteria: (1) population (children with neuromotor or neuromuscular impairments) (2) intervention (aquatic programme) (Figure 1).

Studies that met the inclusion criteria were individually analysed and summarized on a standardized form incorporating seven headings: (1) article reference; (2) pathology according to the authors description; (3) sample size describing the number of participants included in the study with subgroup participation; (4) research design evaluated according to grading levels of evidence; (5) intervention included total length, intensity (weekly sessions), duration of each session and technique used; (6) outcome measures as described by author and (7) results.

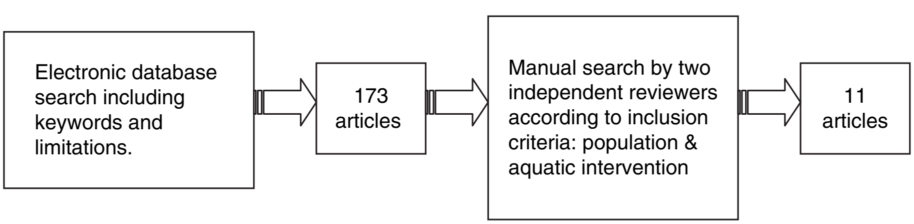

Figure 1 Flow of data retrieval procedure.

In order to determine the quality and efficacy of a specific intervention trial, the level of evidence of the research design was evaluated by two independent evaluators using a single grading system (Table 1). Nine of the articles (82%) were given the same grade, and two articles (18%) were graded differently. These articles were judged by a third expert who was a member of a sports science faculty, and consensus was reached. This grading system was derived from Siebes *et al.*[15] who applied an adaptation of Sackett's method for grading research[16] with modifications supported by research of the American Academy for Cerebral Palsy and Developmental Medicine.[17]

Results

The initial search of the electronic and manual databases identified 173 titles and abstracts which met the search criteria. Of these articles 11 met the inclusion criteria. The articles were published in 10 different journals between the years 1974 and 2003. The findings of these 11 studies are summarized in Table 2.

A total of 173 participants were studied across five main populations from the articles selected in this review (Table 3). The participant population most frequently studied was children and adolescents with cerebral palsy ($n = 114$; 63%). Dorval *et al.*[21] did not describe the subtypes of the cerebral palsy participants in the study in terms of functional levels in relation to the types of cerebral palsy. It is therefore impossible to assess the overall distribution of the various subtypes of cerebral palsy among the research participants. Topographical classification of participants with cerebral palsy in this review revealed a majority with diplegia ($n = 45$; 39%) and hemiplegia ($n = 35$; 31%), while the second most prevalent condition was muscular dystrophy ($n = 54$; 33%). Additional populations included Rett syndrome ($n = 1$; 1%) and infants at risk ($n = 4$; 2%). The age ranges of the samples studied were highly diverse and included children from the age of two months to 19 years. Cuhna *et al.*[20] included an even broader age group in their study, ranging from 1 to 40 years. Despite the fact that their study included adults, it was included in the present review since the majority of the participants met the inclusion criteria.

Of the 11 selected articles (Table 2), only one article was rated level I[21] evidence, two articles were rated level II[6,23] evidence, and three articles were rated level IV.[20,25,27] The remaining articles were rated as level V evidence. This category incorporated individual case reports without employing control participants or multiple baseline designs.

The intervention durations across articles ranged from six weeks to two years.[26] Only one article[22] did not specify the duration of the intervention period. Six studies[19,20,6,23,26,27] applied aquatic interventions twice a week and two studies[21,24] applied it once a week. The remaining three articles did not specify the frequency of the aquatic session applied. The most frequent duration of session specified was 30 min,[6,20,23,25] which was reported in four articles. However, four articles[19,22,24,26] did not indicate the duration of each aquatic session.

The most common method employed for intervention in the aquatic environment were the Halliwick method[19,20,21,24] and adapted swimming lessons.[21,25,26] Only one study[21] described the

Table 1 Levels of evidence for grading research[15,16]

Level	Group research	Single individual research
I	Randomized control trials	$N = 1$ randomized control trials
II	Non-randomized control trials Prospective cohort studies with concurrent control group	ABAB design Alternating treatments (e.g. ABAB) Multiple baseline across participants
III	Case studies with control participants Cohort studies with historical group control	ABA design
IV	Case series without control participants	AB design
V	Case reports Non-empirical methods	Case reports Non-empirical methods

Table 2 Summary of articles

Reference	Age (years)	Pathology	Sample size	Level of evidence	Programme details	Outcome measures	Results
6	5–7 (5.7 Av)	CP Spastic D Spastic H Spastic Q Ataxia and Athetosis	46	II	Once a week (30 min) exercise Twice a week (30 min) aquatic 6 months	Vital capacity Water orientation	Combined land and aquatic intervention is likely to improve respiratory function
18	4–5.5–9.5 months	Neurological dysfunction	1	V	5 months daily exercise	Gross and fine motor skills	Walked at 10 months with minimal abnormal movement patterns
19	11	Rett syndrome	1	V	Twice a week for 8 weeks Halliwick	Stereotypical movement analysis Functional hand usage Hand skills Gait and balance Hyperactive behaviour Communication and social interaction	Decrease of stereotypical movements Improvement of walking balance Increase in environmental interaction Decrease in hyperactive behaviour and anxiety
20	(SMA) type I & II 1–10 years Type II 6–40 years	SMA type I & II	50	IV	Physiotherapy once a week Hydrotherapy (Halliwick) twice a week 48 months	ROM–lower extremities Muscle strength (manual muscle test) Barthel Ladder (ADL)	93% type II & type III showed improvement in ADL
21	10.2–17.3	CP: Q, D, T, DH.	20	I	Once a week (55 min) 10 weeks	Leisure's Activity Inventory, Rosenberg's Self-Esteem Scale Functional Independence Measure for Children (WeeFIM)	No significant group differences were found between the conventional aquatics programme and the adapted aquatics programme across the three outcome measures
22	1	SMA	1	V	Aquatic intervention frequency and duration not stated	Active ROM Exercises and vestibular stimulation in an upright position	More activity and increase in weight without loss of muscle strength
23	5–7 (5.7 Av)	CP Spastic D Spastic H Spastic Q Ataxia and athetosis	46	II	Once a week (30 min) exercise Twice a week (30 min) aquatic 6 months	Matrinek–Zaickowsly Self-Concept Scale Water orientation skills	Significant improvement in orientation skills No improvement of self-concept

24	8	Spastic D	1	V	Once a week for 6 weeks Halliwick	***GMFM***: 88 Items ***SWIM***: Swimming with Independent Measurement 11 items scores range from 1 to 7 total score of 77	Improvement in SWIM scores 34/77 to 52/77 GMFM to 91% to 96% Improvement in standing and balance
25	11-15	PMD	3	IV	11 months P1: 4 months Twice a week (30 min) swimming Once a week IPPT P2: 3 weeks without therapy Twice a week (30 min) swimming 2 weeks IPPT P3: 2 weeks without therapy 5 times a week 4 weeks (20 min) swimming	Vital capacity (VC)	Increase in VC 3–14% throughout phases. Decrease in VC without swimming
26	14	Spastic RH	1	V	Twice a week 8 weeks swimming water safety instruction	ROM of shoulder joint Increased function and co-ordination of extremity during bilateral activities Increasing bilateral co-ordination during activities Increasing balance and equilibrium skills Promotion of a positive self-image	Improvement in ROM increase of 15° in shoulder flexion and 10° abduction Arm swing during ambulation implying an improvement in gross co-ordination Use of right extremity in ADL Back and side stroke + crawl
27	2–5 months	High-risk infants	3	IV	Warm water emersion and hydrotherapy 20 sessions	Heart rate (HR) Blood pressure (BP) Brazelton Neonatal Behavioral Assessment Scale	Increase BP, HR and behavioural state after both types of interventions

CP, cerebral palsy; Q, quadriplegia; D, diplegia; T, tetraplegia; DH, double hemiplegia; PMD, progressive muscular dystrophy; SMA, spinal muscular atrophy; RH, right hemiplegia; ROM, range of motion; ADL, activity daily living; IPPT, intermittent positive pressure therapy; GMFM, Gross Motor Function Measure.

Table 3 Investigated population

Investigated population	Number of trials	Number of participants	Mean age (years)
Rett syndrome	1	1	11
Neurological dysfunction	1	1	0.8
High-risk infants	1	3	0.3
Cerebral palsy	5	114	19
Hemiplegia		35	
Double hemiplegia		3	
Diplegia		45	
Triplegia		2	
Quadriplegia		21	
Ataxia/athetosis		8	
Muscular dystrophy	3	54	7
SMA type II		31	
SMA type III		20	
PMD		3	

SMA, spinal muscular atrophy; PMD, progressive muscular dystrophy.

swimming routine employed and the two articles incorporating swimming did not describe the content of their routine in detail. An additional aquatic intervention was warm water immersion.[27] The remaining studies did not specify the type of treatment employed in the aquatic environment.

An important factor when working in the aquatic environment is the water temperature. The different reactions of the body when immersed in water of different temperatures have been well documented.[4] Four articles[20–22,27] specified an average water temperature of 33°C.

Fourteen measurement results were identified in the 11 articles included in this review (Table 2). Only six studies reported reliability and validity of their measurements. With regard to the contextual factors, all interventions were applied in the aquatic environment. Only one article[21] reported group sessions of five, while the remaining articles reported individualized sessions.

Our rating procedure found the following distribution of outcome measures reported: Five articles reported improvement in body functions,[6,22,25–27] one article[6] showed statistically significant results in the function dimension of vital capacity.

Five articles reported improvement in activities that included gross and fine motor skills,[18] gait and manual skills,[21,24] gross motor function and swimming skills,[21,24] bimanual co-ordination[26] and items rated on the neonatal behavioural scale.[27] However, none of these articles reported results of statistical significance. One article[21] reported no statistical significant difference between group effects in terms of functional independence as measured by the Functional Independence Measure for Children (WeeFIM). However, in this particular article both groups received aquatic interventions. The authors drew a comparison between adolescents with cerebral palsy who received hydrotherapy and adolescents in the control group who received traditional swimming lessons.

Four studies[19,21,23,26] measured the influence of aquatic interventions on participation outcomes. Two articles reported improvement in communication skills, social interactions[19] and self-esteem.[26] Two additional articles[21,23] reported no statistical differences in self-esteem as measured by the Rosenberg Self Esteem Scale[21] and self-concept as measured by the Martinek Zaickowsky Self-Concept Scale.[23]

Discussion

Our findings are consistent with the dominant representation of participants with cerebral palsy in the paediatric population described as having neuromotor impairments. [28] Literature reviews of participants with paediatric neuromotor impairments have documented the effects of pain,[29] strength training[13,30] and neurodevelopmental treatment[17,31] and have noted a similar heterogeneity within this population in terms of classification and severity. Out of the 173 participants included in the articles reviewed here, a wide variability was evident regarding age and intervention outcome (Table 2). Sweeney[27] used the aquatic environment to enhance blood pressure and heart rate in high-risk infants aged 2–5 months. When reflecting on outcome measures related to an older paediatric population, the warranted outcomes of aquatic intervention would be decreasing heart rate through reducing energy expenditure and increasing the duration of independent movement. Furthermore, previous studies have revealed that exercise in the aquatic environment in full immersion (shoulder height) results in lower heart rate during exercise than on land.[32]

Because of the diversity of characteristics in paediatric neuromotor impairments it is difficult to conduct large group randomized control trials. Therefore it is acceptable to apply small group interventions to investigate the effectiveness of a well-described intervention on specified outcome variables.[33] The level of evidence of a specific research design allows clinicians to consider a specific treatment critically: a rigorous research methodology will produce greater assurance of treatment outcomes.

Eight of the 11 articles were rated as lower level IV and level V evidence, suggesting that the effectiveness of aquatic interventions, as reported in these articles, cannot be regarded as evidence-based practice. Four of the articles were quasi-experimental,[6,20,21,23] two were single-subject designs[25,27] and five were case reports.

Siebes *et al.*[15] reported significant improvement regarding the methodological characteristics in studies that implemented therapeutic interventions in children with cerebral palsy between the years 1990–2001 (66% level I and II studies) as compared to similar studies conducted between the years 1980–1989 (32% level I and II). Such an improvement was not prevalent in our findings. On the contrary, our findings show that the majority of the studies did not use control groups and so could not identify the effects of aquatic interventions in children with neuromotor impairments in comparison to other treatments or no treatment at all. Dodd *et al.*[13] also noted limitations in methodological designs regarding the effects of strength training in populations with cerebral palsy.

In contrast, the majority of recent studies on adult populations that examined the effectiveness of aquatic interventions employed moderate to high-quality research designs.[10]

Our review found a broad range of programme intensities and session durations. This variability in aquatic interventions conducted across older populations was also noted by Geytenbeek.[10] Five articles did not specify the intensity of the sessions. Several studies compared the effects of programme intensity on outcome measures,[34,35] but they gave insufficient information regarding the techniques employed in the aquatic environment to allow replication. Six of the 11 articles (55%) noted the techniques employed, but only one article[26] described the swimming routine.

Authors in 5 of the 11 articles described their findings as having a positive effect on body functions, specifically vital capacity[6,25] and range of motion.[20,22,26] These outcomes may be related to the specific characteristics of the aquatic environment with respect to hydrostatic pressure (vital capacity), and to the relaxing effect of water temperature and turbulence on range of motion. Hutzler *et al.*[6] found a 63% increase in vital capacity in kindergarten age children with cerebral palsy who received aquatic intervention in comparison with land-based intervention (23%). Majorie *et al.*[25] employed a BAB single subject design in three children with progressive muscular dystrophy and found that vital capacity increased. However, the articles[20,22,26] that reported a positive effect on range of motion failed to report the tools that were used to measure the outcome scores. Therefore, the findings of these studies with respect to the effectiveness of aquatic interventions on range of motion cannot be regarded as evidence.

Recent studies have emphasized the importance of outcomes to daily activity when employing therapeutic interventions.[36,37] Eight of the articles in our review[6,18–21,23,24,27] measured the effects of aquatic interventions on activity in children with neuromotor impairments. Two of these articles[18,19] did not employ reliable tools to measure the outcome and therefore are insufficient. All the articles except one[21] reported positive effects of aquatic interventions on activity

Clinical messages

- There is evidence to suggest that hydrotherapy might improve respiratory function in children with cerebral palsy.
- In other aspects of function (activity and participation), further research of good design is needed.
- Outcomes need to be related to the likely benefits of the aquatic environment and the intervention.

outcomes. Furthermore, no adverse effects were reported.

A noted difficulty in studying outcome effects in children with neuromotor impairments is the lack of assessment tools sensitive enough to detect change over time.[15,38] Furthermore, assessment tools employed need to be valid and reliable in terms of characteristics of the research population such as age and diagnosis, and outcome objectives (i.e. improvement in activity level or participation).[38] Cuhna *et al.*[20] used the Barthel scale to assess functional change in people with spinal muscular atrophy between the ages of 1 and 40 years. Although this scale has been found to be reliable[39] and valid[40] it has only been recommended for use in stroke patients.[38] Therefore, the validity of the outcome effects is questionable. Dorval *et al.*[21] used the WeeFIM to assess activity outcomes when comparing adolescents who underwent hydrotherapy with adolescents who underwent sessions of traditional adapted aquatics. Although the WeeFIM has been proven to be a valid and reliable tool, it has yet to be validated in terms of responsiveness to change.[38] This may explain why no statistical differences were found between the groups. In contrast, Mackinnon[24] used the Gross Motor Function Measure[41] to assess an 8-year-old boy with cerebral palsy (spastic diplegia) before and after aquatic intervention and noted improvement in his standing balance and his ability to walk up and down stairs. The Gross Motor Function Measure is considered to be one of the most reliable and valid scales in terms of responsiveness to change.[38] The rationale of using aquatic intervention for improving activity outcomes has not yet been explored.

When establishing outcome effects it is necessary to suggest a theoretical model for explaining the results that are attained.[42] For example, it is well established that the kinematics of walking in the water are different from those of walking on land.[43] Authors are required to provide a rationale for recommending aquatic activities for improving activity on land. Such rationales could vary when dealing with practice suggested by the schema theory[44] and the ecological theory.[45]

Four studies measured participation criteria in terms of communication and social interaction,[19] self-esteem,[21] self-perception[23] and self-image.[26] Two articles[19,26] were case studies and did not describe the criteria used for measuring communication, social skills and self-image. This evidence is therefore not conclusive. However, Pegaanoff[26] reported that after completing the aquatic intervention, her participant felt sufficiently confident to join a community swimming programme. Hutzler *et al.*[23] reported no change in self-perception in children who received aquatic interventions in comparison with children who received land-based interventions. They attributed their results to the limited attainment of independent swimming. These results may suggest that participation-driven programmes should be aimed at achieving independent aquatic performance.

In most cases the information that was given to summarize the nature of the intervention was very limited. This made it very difficult to evaluate the effectiveness in terms of the details of the intensity, duration and exercise in each form of aquatic intervention. The wide variability in outcome measures across the studies presented an additional limitation. This variability reduces the ability to replicate particular intervention programmes in terms of intensity, duration and content.

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