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The impact of swimming and other aquatics on human development, physiology, and the course of some diseases

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Abstract

Introduction: In our work, we decided to connect physical activity and hydrotherapy as well as explore the impact of water-based physical activity on human organisms. We focused on the effects on physiology and body development. We also analysed studies that research aquatics activity as a method of treatment. We aim to present scientific evidence about using in-water activity in prevention and rehabilitation. We believe our synthesis of recent discoveries will help many medical specialists in their everyday work.

Review method: We analysed the newest research conducted from 2015 to 2024. The studies were searched in online databases like PubMed and Google Scholar. We focused on the impact of aquatic physical activity on human development, physiology, and the course of diseases, especially as a form of preventing and rehabilitating illnesses.

Results: Physical activity in water has a beneficial influence on the cardiorespiratory system and can be used for both prevention and rehabilitation. What is more, aquatics can be considered as a method of hypertension treatment. Water exercises can be one of the forms of rehabilitation after cardiac procedures like percutaneous coronary interventions and even heart transplants. They are well-tolerated among patients with chronic obstructive pulmonary disease even if physical comorbidities are present. Swimming can be used as a rehabilitation and even one form of asthma treatment in the paediatric population. Swimming can improve insulin sensitivity, glucose control and reduce biomarkers of endothelial activation. What is worth noticing is the positive impact of water exercises on the cardiovascular system and reduction of pain and stiffness that lasts in long-term follow-up. There is data suggesting that the water environment exercises have a beneficial impact on patients with autoimmune diseases like ankylosing spondylitis, rheumatoid arthritis and fibromyalgia. Patients suffering from osteoarthritis can benefit from aquatics as well. A positive impact was observed on the population suffering from ADHD and autism spectrum disorder. The diving by the Bathysmed® protocol seems to decrease symptoms of PTSD. The negative impact of intensive swimming training on mental health was observed and moderate swimming training was fully enjoyable for young students. Research conducted on the paediatric population shows that swimming training can benefit motor development. Even short-time swimming can develop motor skills. One of the studies shows a decrease in body fat and an increase in aerobic capacity among children with Down Syndrome who were practicing swimming. There were no observed impacts of aquatics on IgA levels. In contrast to that swimming can improve the level of TNF α and HSP70. What was relevant in that research is that immunological protein level as well as response after intervention can be related to genetic variability.

Conclusions: Recent studies show a positive influence on human development, physiology, and the course of some diseases. They suggest that aquatics can be used as a form of preventing, rehabilitating and even treatment of some illnesses. The conclusions from recent studies need to be confirmed in further research because of their limitations.

Keywords: Aquatics, physical activity in the water, cardiovascular system, respiratory system, obesity, mental health, autoimmune diseases, rheumatology, development of children, biochemistry

Introduction

I choose a lazy person to do a hard job. Because a lazy person will find an easy way to do it. The quote by Bill Gates is a synthesis of human nature which drives our civilisation to the development of technology. Thanks to this our life is easier and our generation has possibilities which were impossible a few centuries ago. The dark side of that process which has a poor

impact on our health is the deprivation of physical activity. The movement was a natural way of functioning for our ancestors. Today it becomes an investment in our health. The scientific community emphasises the value of physical activity by showing that it reduces the risk of cardiovascular diseases¹. The gravity of the problem is accentuated by the fact that institutions like WHO and the EU cover the subject in their documents²³⁴⁵⁶.

Hydrotherapy is one of the oldest methods of therapy. It was known in many antique cultures like ancient India, China, and Japan. In Europe the father of medicine- Hippocrates used hydrotherapy as one of his methods. That tradition was developed through centuries and is still availing these days.

In our work, we decided to connect physical activity and hydrotherapy as well as explore the impact of water-based physical activity on human organisms. We focused on the effects on physiology and body development. We also analysed studies that research aquatics activity as a method of treatment. We aim to present scientific evidence about using aquatics in prevention and rehabilitation. We believe our synthesis of recent discoveries will help many medical specialists in their everyday work.

Review method

We analysed the newest research conducted from 2015 to 2024. The studies were searched in online databases like PubMed and Google Scholar. We focused on the impact of aquatic physical activity on human development, physiology, and the course of some diseases, especially as a form of preventing and rehabilitating some illnesses.

Impact on the cardiovascular system

The influence of swimming on arterial function, muscular strength, and cardiorespiratory capacity in postmenopausal women with moderate hypertension was examined by Wong et al.⁷. It was proved that swimming training 3 to 4 times a week caused significant improvement in both systolic and diastolic blood pressure (SBP and DBP), arterial stiffness, muscle strength, and aerobic capacity comparing to no changes in the control group without such training. The authors concluded that this way of training may be beneficial in preventing and treating lifestyle-related: vascular disease, decrease of muscle strength and reduction of cardiorespiratory capacity. It is worth noticing that this study only qualified a specific group of patients- postmenopausal women with a sedentary lifestyle and stage two hypertension however outcomes of this trial are promising and can be a starting point for performing research in a more diverse population.

Lee et al. compared treadmill walking with walking in the water and no exercises groups⁸. Examined groups consisted of elderly adults with coronary artery diseases after percutaneous coronary intervention and with limited movement due to lower limb osteoarthritis. It was shown that there are no significant differences between the treadmill walking and aqua walking group in a decrease of percentage body fat, total cholesterol level, resting heart rate and the increase of cardiopulmonary efficiency. In contrast, significant changes were observed between these groups and the control group without exercises. The authors stated that walking in the therapeutic pool can be considered as an alternative way of exercising with patients with restricted ambulation during cardiac rehabilitation. However, researchers pointed out some limitations such as a small sample of contestants and difficulties with generalizing the results to a wider population due to the need for specialized staff and rehabilitation ward to perform aqua walking. Considering the outcomes, this method of exercise should be recommended as part of an exercise-based rehabilitation program for patients with coronary artery disease who are limited by lower extremity osteoarthritis.

Castro et al. performed another trial comparing water and land-based exercises in patients after a heart transplant⁹. Outcomes have shown that in clinically stable patients after heart transplant SBP and DBP decreased with no significant difference between interventions when it comes to 24-hour ambulatory blood pressure measurement. It suggests that water exercises should be

considered as a tool to oppose hypertension in this small but high-risk group of patients. Limitations of this study were: a small group of patients and a lack of long-term follow-up. However, it showed that the acute effects of in-water exercise are safe for patients after heart transplants. We hope that it will provoke multicenter longitudinal RCTs with a wider sample to confirm the presented results.

Another research by Bocalini et al. examined the acute effects of water ergometry¹⁰. A comparison of results of land and water exercises showed that 90 minutes after the training session there was a significantly higher prevalence of post-exercise hypotension in the water-ergometry group. The hypotensive effect was more visible in untreated hypertensive patients compared to treated hypertensive or normotensive groups. Exercise in the water was also more effective in restoring heart rate variability, especially in untreated hypertensive subjects. Authors suggested that water ergometry can be recommended for blood pressure control and autonomic modulation to lower cardiovascular risk. However, researchers stated that a larger, long-term study on a more diverse population should be performed but it seems like water-ergometry is a highly effective and low-injury strategy to decrease cardiovascular risk.

The respiratory system and pulmonary disease

McNamara et al.¹¹ researched elderly patients with chronic obstructive pulmonary disease and physical comorbidities undergoing a water-based exercise training programme in a hospital hydrotherapy pool. Contestants were asked to fill out a questionnaire about their experience. The results show that aquatic environment and water-based exercise are well accepted and the majority (89%) of the participants want to continue water-based training. This study suggests that water environment exercises can be used as physiotherapy in that population. However because of a small group of examined patients further studies need to be conducted to confirm that thesis.

Tizar et al. examined the influence of swimming on asthmatic children population (6-18 years). The examination protocol included free swimming exercises for 60 minutes per session, 3 days a week for 8 weeks. A study has shown that frequent swimming exercises significantly improved FEV₁ and FVC among the examined group¹². The authors concluded that swimming workouts can positively affect asthma treatment and appear to improve the development of asthmatic children¹². What is worth to notice the researchers aimed to examine the paediatrics. There is a need for further studies to discover how swimming impacts in broader population.

Obesity

Another asset of the aquatones is their positive impact on obesity and its implications like joint pain, fatigue, stiffness, insulin resistance, hyperglycaemia, or hypertension. Casilda-López et al. proved that an 8-week dance-based aquatic exercise program in obese postmenopausal women with knee osteoarthritis significantly improved function and cardiorespiratory capacity¹³. Moreover, it decreased postexercise heart rate (101/min in baseline vs. 82/min in posttreatment) and fatigue. It also reduced pain in the experimental group and stiffness. What should be highlighted, the improvements continued to show significant differences in all aspects at 3-month follow-up in participants in the experimental group compared with those in the control group.

In another study a different strategy of swimming training was compared to no intervention group concerning metabolic syndrome rates in inactive middle-aged women with mild hypertension. Connolly et al. showed that 15 weeks of low-volume high-intensity intermittent swim training improves insulin sensitivity, glucose control and reduces biomarkers of endothelial activation¹⁴.

Although promising impact of aquatones on obesity and its complications, more data should be investigated because of the limitations of the above studies like small observed groups, only female patients, and a narrow range of age.

Rheumatology

Soufivand et al. compared the effects of the six-week Aqua Pilates and Aqua Stretch training program on pain, function, and quality of life in patients with ankylosing spondylitis¹⁵. The authors observed significant changes in all examined variables except for chest expanding in the Aqua Stretch group. Quality of life, 6-minute walk test, and Schober flexion increased, while Bath Ankylosing Spondylitis Disease Activity Index, visual analogue scale of pain, fatigue and Schober extension showed significant decreases. Similarly, in the Aqua Pilates group, all the parameters showed significant changes except for chest expansion and Schober extension. This study pointed out some benefits of water-based workouts for ankylosing spondylitis patients in the mid-term perspective. Future well-designed studies are needed to better understand mechanisms and potential interventions to improve patients with ankylosing spondylitis.

Siqueira et al. performed a randomized clinical trial to examine the effectiveness of in-water exercises in women with rheumatoid arthritis¹⁶. Muscle strength, disease activity, functional ability and body densitometry were measured in aquatic exercises, land exercises and control group. After 16 weeks of intervention, which was performed 3 times a week there were no significant differences in muscle strength measured by isokinetic dynamometer. Also, body composition measured by total body densitometry did not show significant changes among the groups. What is interesting, disease activity (Disease Activity Score- DAS28) and functional ability (health assessment questionnaire) in the aquatic exercises group significantly improved. The water-based program provided significant improvement in disease activity, pain, and functional capacity. In addition, reduction of daily NSAIDs intake and enhancement of patients' overall perception was observed in water-based group. Therefore, in-water exercises should be considered as a part of non-pharmacological treatment in patients with rheumatoid arthritis. Authors pointed out that similar programs have a relatively high dropout rate: approximately 30%^{17,18,19} but in their study, it was only 20%, probably because of high motivation and individualized approach to the patients provided by a multidisciplinary team.

Another RCT was performed to compare swimming and walking in patients with fibromyalgia²⁰. Fernandes et al. randomly divided 75 women into walking and swimming groups. Both interventions consisted of 50-minute exercise sessions 3 times per week for 12 weeks. In the swimming group the intensity was set at heart rate 11 under the anaerobic threshold, whereas in the walking group at the anaerobic threshold. The authors did not find significant differences between the groups regarding pain, functional capacity, quality of life and aerobic capacity. In both interventions participants experienced improvement in examined variables. In conclusion, swimming, similar to walking, is a beneficial method for decreasing pain and improving functional capacity and quality of life in patients with fibromyalgia.

The impact of aquatones on patients with osteoarthritis was observed in recent studies. Rewald et al. proved that a 12-week aquatic cycling improves self-reported knee pain and physical functioning in 50-70 years old participants with mild-to-moderate knee osteoarthritis compared to usual care²¹. These results are confirmed in other researches. Alkatan et al. compared swimming and cycling exercise interventions in patients with osteoarthritis. This study proved that swimming exercise intervention is found to show significant reductions in joint pain, stiffness, and physical limitations in patients with osteoarthritis. Moreover, participants showed improvements in functional capacity (increased maximal handgrip strength, isokinetic knee extension and flexion power) and the distance in the 6-minute walk test. What should be highlighted, the benefits from swimming exercises were similar to land-based cycling training²². Munukka et al. confirmed that progressive aquatic resistance training in postmenopausal women with knee osteoarthritis significantly decreased the stiffness dimension in the training group compared to the controls only short term (4 months). However, after the

cessation of the training, the benefit was no longer observed during the 12-month follow-up. Furthermore, participation in an intensive aquatic resistance training program did not have any short- or long-term impact on pain and physical function or quality of life in women with mild knee osteoarthritis, except for short-term decreased stiffness in the training group²³. Alonso-Rodríguez et al. explored the efficiency of hydrotherapy in primary total knee prosthesis due to osteoarthritis in comparison to gym treatment. Higher clinical improvements were observed in the pool group, with statistically significant differences in pain, stiffness, joint balance, and muscle strength in the operated knee, and the result of the 6-minute gait test. This study confirmed that hydrotherapy during the second phase of rehabilitative treatment was more effective than gym physiotherapy²⁴. Those studies give some view of application of aquatics in osteoarthritis but because of limitations in these researches like small number of participants and no diversity amount of contestants there is a need for further trials.

Mental health and psychiatry

A randomised study was conducted on treatment alternatives in children with attention deficit hyperactivity disorder (ADHD). This disorder is considered the most common neurodevelopmental disorder in children. It is characterized by inattention, hyperactivity and impulsivity. Treatment can include pharmacological, non-pharmaceutical and multiple therapeutic approaches. This study proposed a twelve-week recreational swimming program as an alternative treatment for ADHD. Children with ADHD of varying severity from different schools were studied. It turns out that the introduced recreational swimming program had a positive effect on the behavioural, cognitive and academic performance of children with ADHD. This leads us to believe that swimming exercises can be a useful tool for working with children with ADHD as one of the alternative therapeutic options²⁵.

Another study addressed the effects of water training on the functioning of children with autism spectrum disorders. These disorders consist of significant impairments in behaviour and communication and are caused by multifactorial and neurodevelopmental disorders. They are detected in early childhood and persist into late life. Children with autism spectrum disorders also have motor and postural abnormalities and worse coordination and balance than typically developing children. The following study examined the effects of aquatic exercises and karate kata on static and dynamic balance abilities in children with autism spectrum disorders. The study was conducted on a group of children who were divided into training and control groups. The training group received water exercises and karate kata, while the control group was told to maintain their current routine. The results show that doing ten weeks of karate training and water exercises contributes to the improvement of balance abilities. This allows us to conclude that the introduction of this type of activity in children at school, for example, could help improve balance abilities in a population of children with autism spectrum disorders²⁶.

Post-Traumatic Stress Disorder (PTSD) is a chronic condition for which no effective treatment has yet been found. However, one article has looked at this problem and conducted a study involving the introduction of a specially designed Bathysmed® mindfulness immersion program. The Bathysmed® protocol is an innovative form of diving that combines the experience of diving with psychoeducation in sophrology, including breathing techniques. It requires concentration, openness to the experience, self-acceptance and care. Focuses on breath control and body awareness. Consists of 10 group dives over 6 days. Each session consists of dive theory, psychoeducation, dive exercise review, mental preparation and meditation diving. For this purpose, the study subjects were divided into two groups. In one, the subjects participated in a multisport program, and the other in the Bathysmed® protocol. The results suggest that the Bathysmed® program produces more favourable results in reducing intrusion symptoms of PTSD after one month than the multisport program. This shows the value of the Bathysmed® protocol, but further research on this topic is needed²⁷.

One research paper examined the effects of high-volume training on the mental state of the

competitive swimmers studied. High-volume training is when a participant improves his aerobic capacity, leading to optimized performance. To study the issue, a randomized controlled trial was conducted to evaluate the effect of four weeks of swim training on mental state and swimming performance. All variables were measured before and after training. The study showed a negative effect of high-volume aquatic training on swimmers' mental state compared to standard training program. The sudden increase in the training load led to increased anxiety, which translated into reduced self-confidence²⁸.

Impact on children's health and development

According to the concept of “embodied cognition” motor development is connected to cognitive and language processes. Motor development is especially important in early life when a child interacts and learns from the environment. Baby swimming allows infants to perform movements that they cannot do on the ground. Although the relations between baby swimming and motor development has not yet been fully investigated studies by Borioni et al. and Leo et al. show promising results^{29,30}. In both studies, infants were assigned into a group that regularly carried out aquatic courses and a control group with no swimming exercises. Borioni et al. controlled motor development with the Peabody Developmental Motor Scales (2nd edition, PDMS-2) and cognitive development with core tests of executive functions and Leo et al. used PDMS-2 for assessment of development. It was shown that children in the experimental group although younger than the control group showed greater levels of motor development after swimming training. Notwithstanding those findings are not definitive due to methodological limitations they seem to support swimming influence on early motor development in infants and toddlers.

Another research by Karatrantou et al. is a multi-aim trial studying the efficacy of a swimming lesson, during the physical education course³¹. The authors measured the enjoyment of classes too. The aquaticity was evaluated by protocol proposed by Varveri et al.³² Results show that the short-term swimming program significantly improved aquatics skills. What is more, the experience of training was highly enjoyable for the participating students (92,2% of students were satisfied). It seems that swimming classes, even short-term, can prevent drowning among children and are an enjoyable way of spending time for students.

In another article, researchers focused on the effects of swimming on teenagers with Down Syndrome. For this purpose, a group of teenagers was divided into two subgroups: training and control. The training group participated in a special swimming program for 33 weeks, while the control group maintained normal physical activity. Before the study, none of the controlled parameters differed significantly between the groups. However, after the experiment, the differences were noticeable. The training group showed a decrease in body weight, body fat and BMI, while the control group had a significant increase in these variables. In addition, the training group showed a marked increase in aerobic capacity, while VO₂ max decreased in the control group. Moreover, after the study period, the training group showed an increase in arm and trunk strength, as well as increased endurance and functional strength. The swimming skills of the training group also improved. No such changes were observed in the control group. This study suggests that the activity program introduced in this group of adolescents may be an effective way to combat lifestyle diseases, even for those with Down Syndrome³³.

Biochemistry

Studies show that physical activity in older people extends life expectancy, and improves their physiological status and quality of life. Older people who exercise regularly have better immunological profiles than older people with sedentary lifestyles. A 2015 study examined whether hydro gymnastics can improve serum IgA levels in older people. It examined people aged 60 or older, who were divided into two groups: control and experimental. The experimental group was treated with hydro gymnastics, while the control group did not perform

these exercises. Unfortunately, there were no significant interactions between the groups and measurements of IgA³⁴.

In the research by Kotowska et al., the connection between 12-week swimming training and the level of tumor necrotic factor α (TNF α) and HSP70 was observed³⁵. These parameters are affiliated positively with lipid peroxidation and antioxidant enzyme activity. Contestants were selected among healthy young men. It was observed that patients with different IL-6 and HSP70 genes had different baseline levels of inflammatory parameters and prooxidant-antioxidant status and/or noticed different changes in response to 12-week swimming training. The intervention seems to reduce the inflammatory process by lowering serum levels of TNF α and HSP70 without regard the genetic status. Homozygous wild-type genotypes of both IL-6 (GG) and HSPA1A (GG) appear to have lower baseline levels of inflammatory stress markers and stronger responses to swimming training.

Discussion

The studies which we have taken cognisance of show that physical activity in water has a beneficial influence on the cardiorespiratory system and can be used for both prevention and rehabilitation. What is more Wong et al have shown that because of its beneficial impact on the normalisation of blood pressure aquatics can be considered as a method of treatment⁷. Bocalini et al. suggest that water exercise outrival results from land exercises in lowering blood pressure¹⁰. Another study among the elderly population has shown that this form of intervention has comparable results as land-based exercises⁸ and broadens the potential method of physiotherapy. Water exercises can be one of the forms of rehabilitation after cardiac procedures like percutaneous coronary interventions and even heart transplants⁸⁹. Although promising results of the above studies there is a need for further investigations to confirm that data.

There are propositions that water exercises are well-tolerated among patients with chronic obstructive pulmonary disease even if physical comorbidities are present¹¹. These promising results show that aquatics can be dedicated to that group of patients especially when other types of exercises are not possible because of their physical limitations. That study is based on the subjective feelings of contestants and needs to be followed by studies which model their conclusions on more objective data. After all that research lays the foundation for further studies. More objective parameters like FEV 1 and FVC were used in another study which examined the impact of water exercises on children with asthma¹². It seems that swimming can be used as a rehabilitation and even one form of asthma treatment in the paediatric population. Unnecessary, study contains a small examination group (20 contestants) and there is a need for confirmation by larger studies. Although limitations of that trial it gives hope for new non-pharmacological method of asthma treatment. There is also a need to check if the same impact is present in the adult population.

There are suggestions that physical activity benefits patients with obesity. Swimming can improve insulin sensitivity, glucose control and reduce biomarkers of endothelial activation¹⁴. Those markers are associated with metabolic syndrome and their normalisation can be promising for dismissing obesity complications. What is worth noticing another trial has shown that a positive impact of water exercises on the cardiovascular system and reduction of pain and stiffness lasts in long-term follow-up¹³. Though studies need to be continued on a larger population, the results are promising because, for frequent joint complications in that population, water exercises are often one of the few rehabilitation methods.

There is data that the water environment exercises have a beneficial impact on patients with autoimmune diseases like ankylosing spondylitis, rheumatoid arthritis and fibromyalgia¹⁵¹⁶²⁰. There is a need for further investigation but the results are promising alternatives for rehabilitation. Another group of rheumatologically patients who can benefit from aquatics are suffering from osteoarthritis²¹²²²³²⁴. Munukka et al. have shown that the

benefits of aquatics are dismissed after cessation of practising²³. That suggests that rehabilitation in that group of patients should not be stopped. What was revealed in that study is that progressive aquatic resistance training gives better results than intense resistance. The results of the research are not harmonious about the superiority of the environment. Alkatan et al. have shown no difference between water and land exercises while Alonso-Rodríguez et al. prove the superiority of hydrotherapy over gym physiotherapy among patients with osteoarthritis after primary total knee prosthesis^{22,24}. That disagreement may be provoked by the variability of exercises in both studies as well as differences between contestants (before- after orthopaedics intervention). To clarify that polarity further studies need to be conducted.

The recent discoveries show that water exercises can benefit mental health. A positive impact was observed on the population suffering from ADHD and autism spectrum disorder^{25,26}. Both of these diseases can handicap daily functioning and increase quality of life. A new method of treatment must be possible. To annex aquatics to daily practices of treatment of diseases there is a need for consecutive investigations. The diving by the Bathysmed® protocol seems to decrease symptoms of PTSD²⁷. To include that method in the guidelines for treatment of that disorder further studies need to be conducted. The negative impact of intensive swimming training on mental health was observed by Chortane et al.²⁸. It seems that these results may be connected with physical exhaustion and pressure to better swimming results. Moderate intense training appears to be safer for mental health. That thesis may be advocated by another study which shows that moderate swimming training (1 per week for 9 weeks) is fully enjoyable for young students³¹.

Research conducted on the paediatric population shows that swimming training can benefit motor development^{29,30}. It is important to stimulate the neurological system from an early age and swimming is one of the opportunities. Despite methodological limitations that research can be a promising foundation for further investigations. Scientists show that short-time swimming can develop motor skills³¹. That suggests that in this population beneficial results from swimming training appear rapidly. What is more water activity can be proposed for children genetically burdened. One of the research shows a decrease in body fat and an increase in aerobic capacity among children with Down Syndrome who were training in swimming³³. That significant finding because in that illness many internal medicine complications are present. Strengthening the cardiorespiratory system can reduce many of them.

Unfortunately, there were no observed impacts of aquatics on IgA levels³⁴. In contrast to that another study evidences that swimming can improve the level of TNF α and HSP70³⁵. Those markers are associated with inflammation and their decrease is beneficial for organisms. What was relevant in that research is that immunological protein level as well as their response after intervention can be related to genetic variability. To precisely examine that appearance further studies need to be conducted

Conclusions

Recent studies show a positive influence on human development, physiology, and the course of some diseases. It can be used as a form of preventing, rehabilitating and even treatment of some illnesses. The conclusions from recent studies need to be confirmed in further studies.

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Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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