Physiological responses to hydrotherapy in physiotherapeutic treatment of coronary patient

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Abstract
For decades, researchers have warned heart patients to avoid water exercise, especially swimming, in order to avoid the risk of adverse cardiovascular complications. More recent research has shown that in patients with coronary artery disease, immersion in thermoneutral water leads to several beneficial physiological responses, yet this research is still scarce. The results obtained show that hydrotherapy is a safe, accessible and appropriate exercise, with almost no adverse events reported in any of the included studies. It could be an effective alternative for those who are unable to participate in conventional exercise programmes. Keywords: exercise, cardio-vascular diseases, water

Fiziološki odzivi na hidroterapijo pri fizioterapevtski obravnavi koronarnega bolnika

Povzetek
Raziskovalci so srčne paciente desetletja opozarjali, naj se izogibajo vadbi v vodi, zlasti plavanju, da bi se izognili tveganjem za neželene srčnožilne zaplete. Novejše raziskave pa so dokazale, da pri pacientih s koronarno arterijsko boleznijo potopitev v termonevtralno vodo omogoča številne koristne fiziološke odzive, vendar je teh raziskav še vedno malo. Pridobljeni rezultati kažejo, da je hidroterapija varna, dostopna in dobra oblika vadbe, saj v skoraj nobeni od vključenih raziskav niso poročali o neželenih dogodkih. Lahko bi predstavljala učinkovito alternativo za tiste, ki ne morejo sodelovati v običajnih programih vadbe. Ključne besede: vadba, srčnožilne bolezni, voda

1. INTRODUCTION

The use of water for therapeutic purposes is probably as old as mankind. Hydrotherapy has been used by different cultures throughout history. The Old Testament mentions the healing powers of mineral water. The ancient Greeks believed that water contained the essence of life. The Bavarian monk Sebastian Kneipp was a great proponent of hydrotherapy and put it on the right footing, laying a foundation that is still largely in place today ("Hydrotherapy", 2017). It is often used in the system of physical medicine and is one of the basic methods of physical therapy. It is known collectively as aquatic therapy or hydrotherapy. The concept of hydrotherapy was developed around 1898. In 1928, Hubbard tubs were introduced. Between the First and Second World War, hydrogymnastics was widely used due to the large number of patients with polio and motor injuries. After 1960, hydrotherapy became more important in prevention - water exercise programmes for the elderly, pregnant women. In the 1970s and 1980s, healthy lifestyles and regular physical activity, including swimming became popular. There are less injuries and less stress on the jointsso aerobic exercise became recommended, also suitable for the elderly and pregnant women. At this time hydrogymnastics is beginning to be used in the early rehabilitation of sports injuries, where dry physiotherapy procedures are limited in the initial period after injury (Lukšič-Gorjanc, 2011).

Cardiovascular cardiac rehabilitation programmes were developed in the 1960s after the benefits of exercise during long-term hospitalisation for coronary events were established. After discharge, rehabilitation continued in the home environment, but the doubts were raised about the safety and supervision of this form of rehabilitation, which led to the development of highly structured rehabilitation programmes that were based solely on therapeutic exercise (Ades, 2001). Cardiovascular rehabilitation is an important part of the continuum of care for cardiac patients. It is part of secondary prevention and its most important element is exercise. The concept of this type of rehabilitation is based on a coordinated physical, social and psychological intervention which affects the underlying risk factors. It encourages a healthy and active lifestyle with the aim of improving quality of life. It is a lifelong process which adapts to the different phases of the disease through appropriate organisational approaches. The content of rehabilitation includes all measures that have been proven to be safe, effective and meaningful. This includes risk assessment, nutritional counselling, aggressive risk factor management, psychosocial support and secondary prevention, which includes protective lifestyle and drug treatment and patient monitoring (Fras & Jug, 2010). Exercise-based cardiac rehabilitation remains a cornerstone of management and secondary prevention in patients with coronary artery disease (CAD). Acute coronary events – such as a recent myocardial infarction and/or coronary artery bypass grafting (CABG) procedure – may impair the ability of individuals to engage in exercise because of cardiac dysfunction, risks associated with the acute effects of exercise, post-procedure recovery, or immediate post-event psychological concerns. In this respect, cardiac rehabilitation – either in outpatient settings or as an intensive short-term residential program – provides sufficient monitoring and reassurance to patients in the immediate aftermath of a recent CAD event, thus empowering them to confidently adopt long-term regular exercise and a healthy lifestyle (Vasić idr., 2019).

Recent research has shown that immersion in thermoneutral water leads to a number of beneficial physiological responses in patients with coronary artery disease (Teffaha idr., 2011), but this research is still scarce. As balneo-rehabilitation planning does not deviate from the basic premises of rehabilitation medicine, hydrotherapy could play a more essential role in the rehabilitation of cardiac patients.

2. METHODS

We used a descriptive method examining the English-language literature published between 2000 and 2021. We searched the electronic databases PubMed, Pedro, Science Direct, April 2021, and in addition, Google Schoolar. We included articles in English and Slovenian. We looked at randomised control trials (RCTs), which are the most important in clinical research because they compare different therapeutic procedures in a statistically valid way. Here, the authors observed and evaluated the physiological effects of hydrotherapy alone or in combination with other therapeutic procedures in the management

of a coronary patient. Depending on the PICO strategy, population, intervention, comparison, control and observed outcome the inclusion criteria were selected as follows. (1) Population: studies including cardiac patients with coronary artery disease (CAD) of both sexes and of all ages. (2) Intervention: physiological responses to hydrotherapy in the management of the CAD patient. (3) Comparison/control: dry exercise training of coronary patients. (4) Observed outcome: physiological responses to hydrogymnastics. We excluded studies in languages other than English as those that did not include cardiac patients, non-randomised control studies, studies from which we were unable to obtain sufficient data for comparison, and studies conducted before 2000.
The literature search strategy, identification of studies, screening, quality assessment and data extraction was based on a review of titles to assess the relevance of the articles and to exclude any that were beyond the scope of this screening. Abstracts were assessed on the basis of predefined inclusion and exclusion criteria. The full texts of the remaining articles that met the inclusion criteria were retrieved and included in the ongoing process for the final decision on inclusion in the systematic review. We used the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) method (Moher et al., 2010) to screen the databases and decide on the applicability of the reviewed sources.
We selected the methodological quality of the studies according to the PEDRO criteria. Each RCT evaluated according to the PEDro scale can be scored from 1 to 10 points, depending on the consistency of the research with the PEDro criteria. Randomised controlled trials scoring 9-10 points are of the highest quality, those scoring 6-8 points are of high quality and those scoring 4-5 points are of low quality. Closely related and determined by the RCT score on the PEDro scale are the levels of evidence. Evidence level 1a - strong evidence is supported either by the results of meta-analyses or by the results of at least two high-quality RCPs. Evidence level 1b - moderate evidence is supported by the results of at least one RCP (Matjačić, 2011).

3. RESULTS

After a selection process, 13 studies were included. The total sample of the 13 studies included 416 subjects with documented CAD and CHF with a mean age of 67.8 years, with a typical sample size of individual studies ranging from 12 to 89 subjects, with an average of 33.8 subjects. The studies were predominantly male, 84.2%. Eight studies included only men, and five studies included both men and women. The ratio was in favour of the male population (Cider idr., 2003, 2005; Lee idr., 2017; Sveälv idr., 2012; Vasić idr., 2019). Three studies included subjects with CAD and CHF (Mourot idr., 2009, 2010; Teffaha idr., 2011) and five included subjects with CAD (Fiogbé idr., 2018; Korzeniowska-Kubacka idr., 2016; Tokmakidis idr., 2008; Vasić idr., 2019; Volaklis idr., 2007), four studies included subjects with ACD (Caminiti idr., 2011; Cider idr., 2003, 2005; Sveälv idr., 2012), and one included subjects with osteoarthritis in addition to subjects with CAD (Lee idr., 2017). All studies were randomised controlled trials. Nine studies compared hydrotherapy with land-based exercise programmes (Caminiti idr., 2011; Cider idr., 2005; Fiogbé idr., 2018; Lee idr., 2017; Mourot idr., 2009; Teffaha idr., 2011; Tokmakidis idr., 2008; Vasić idr., 2019; Volaklis idr., 2007). Caminiti et al. (2011), Cider et al. (2003, 2005), Sveälv et al. (2012), Teffaha et al. (2011a) classified participants according to the New York Heart Association (NYHA) classification, into class II and III. Six studies reported left ventricular ejection fraction (LVEF)[illegible] 35 percent (Caminiti et al., 2011; Cider et al., 2003, 2005; Sveälv et al., 2012; Teffaha et al., 2011a; Vasic et al., 2019). Participants were excluded if they had unstable CHF, peripheral arterial disease, fear of water, any contraindications to testing that could affect the exercise protocol. None of the included subjects recorded gender-specific effects.
The studies lasted from 2 to 24 weeks. Four studies lasted between 2 and 3 weeks (Mourot et al., 2009; Mourot et al., 2010; Teffaha et al., 2011; Vasić et al., 2019), three studies lasted two months (Cider et al., 2003; Korzeniowska-Kubacka et al., Six of the 13 studies lasted three months or longer (Caminiti et al., 2010; Cider et al., 2005; Fiogbé et al., 2018b; Lee et al., 2017; Tokmakidis et al., 2008; Volaklis et al., 2007). The aquatic training sessions lasted between 30 and 80 min, and the frequency of training sessions ranged from 2 to 6 per week.

The studies were carried out in a hospital or spa rehabilitation pools. The depth of immersion in the seven studies averaged 1.25 m (Fiogbé et al., 2018; Mourot et al., 2009; Mourot, et al.; 2010; Teffaha et al., 2011b; Tokmakidis et al., 2008; Volaklis et al., 2007). In three of the studies, the depth was determined according to the xiphoid process (Caminiti et al, 2010; Lee et al., 2017; Vasić et al., 2019) and in two studies the depth was not determined (Korzeniowska-Kubacka et al., 2016; Svealv et al., 2012). Water temperature was determined between 28°C and 34°C in all studies.
Intensity has been reported as a heart rate reserve in five studies (Cider et al., 2003; Lee et al., 2017; Mourot et al., 2009; Mourot et al., 2010; Sveälv et al., 2012), ranging from 40 to 70 percent or as a percentage of VO2 peak in two studies (Caminiti et al). However, in a study (Fiogbé et al., 2018b), target HR was expressed as the ratio between the first and second respiratory threshold. Both thresholds were determined based on visual analysis of respiratory and metabolic responses using the method proposed by Neder and Nery (2000). In five studies, the intensity was determined as a percentage of HRmax (Korzeniowska-Kubacka et al., 2016; Teffaha et al., 2011b; Tokmakidis et al., 2008; Vasic et al., 2019; Volaklis et al., 2007).
All 13 studies were largely unanimous in reporting positive physiological effects of both hydrogymnastics and land-based exercise in patients with CAD and CHF. Some of the important physiological effects of exercise in water include reduction of blood pressure, systolic and diastolic, heart rate at rest and during exercise, peripheral and systemic vascular resistance, pulse pressure (Mourot, Teffaha, Bouhaddi, Ounissi, Vernochet, Dugue, Regnard, and Monpère, 2010; Schmid et al, 2009), reduction in left ventricular ejection fraction, left ventricular end-diastolic diameter, left ventricular end-diastolic volume (Sveälv et al, 2012), increase in minute and pulse volume (Schmid et al., 2007), muscle strength, flexibility and endurance (Colado idr., 2010; Pinto idr., 2014; Volaklis idr., 2007), increase in oxygen consumption, more efficient heart and ventricular function, autonomic cardiac modulation and increase in overall cardiovascular fitness (Cider idr., 2003; Fiogbé idr., 2018; Mourot idr., 2010; Sveälv idr., 2012; Tanaka, 2009; Tokmakidis idr., 2008; Volaklis idr., 2007).

4. DISCUSSION

The results of the studies should be interpreted with caution and the following inclusion criteria should be taken into account: limited or insufficient number of participants in each study, inclusion criteria limited to achieving high loads on a stress test (Caminiti et al., 2010; Cider et al., 2003, 2005; Sveälv et al., 2012; Tokmakidis et al., 2008), stable coronary artery disease, more than 3 months after myocardial infarction (Teffaha et al, 2011a; Volaklis et al., 2007), study conducted in a controlled setting (Shah et al., 2019), inferior study design without comparison groups (Korzeniowska-Kubacka et al., 2016), non-randomised allocation of participants (Tokmakidis et al, 2008), heterogeneity of comparison groups and interventions, underrepresentation or absence of female gender, and lack of consensus among researchers on the core set of outcomes (Cugusi & Mercuro, 2019). Most studies have used aerobic exercise as the primary mode, either alone (cycling, walking, swimming) or in combination with body weight exercises (Lee et al., 2017; Mourot et al, 2009; Mourot, Teffaha, Bouhaddi, Ounissi, Vernochet, Dugue, Regnard, & Monpère, 2010; Teffaha et al., 2011a; Vasic et al., 2019) or with resistance exercises (Tokmakidis et al., 2008; Volaklis et al., 2007). The duration of the studies varied in time, from 2 weeks (Mourot et al, 2009; Mourot, Teffaha, Bouhaddi, Ounissi, Vernochet, Dugue, Regnard, and Monpère, 2010; Teffaha et al., 2011b; Vasić, 2021), 2 months (Cider et al., 2003, 2006; Korzeniowska-Kubacka et al., 2016), 4 months (Fiogbé et al, 2018b; Tokmakidis et al., 2008; Volaklis et al., 2007), up to 6 months (Caminiti et al., 2010; Lee et al., 2017). The frequency of treatments ranged from 2 to 5 times a week, with treatment lasting 30 to 80 minutes. Training intensity was varied and determined based on maximal oxygen consumption determined by cardiopulmonary exercise testing, maximal heart rate or heart rate reserve. For this reason, we cannot accept with certainty all the evidence presented. If we want to discuss chronic adaptations to hydrogymnastics, which are the result of the long-term accumulation of acute responses during a single training session and accumulate over time, the training variables, duration of each session, frequency of sessions, intensity, must be well defined. Chronic adaptation values may increase or decrease over time. In an individual who stops daily exercise, chronic adaptations will decrease and disappear completely (Barbosa idr., 2009). These findings are supported by a study conducted by Tokmakidis et al. (2008). After discontinuation of systematic training some positive physiological adaptations were reduced at 4 months and were restored when resuming exercise in water. This suggests that systematic, permanent hydrogymnastics may improve health status, protect the cardiovascular system and improve prognosis (Tokmakidis et al., 2008).

Cardiovascular and metabolic adaptations are one of the main goals of cardiovascular rehabilitation as they are linked to the prevention of various diseases such as coronary heart disease, hypertension, stroke, obesity or diabetes. Most studies have evaluated adaptations of maximal aerobic capacity between different forms of hydrogymnastics performance (Barbosa et al., 2009). In a study by Vasić et al. (2019), they show that both types of exercise, land and water significantly improved physical performance, measured by VO2 peak which was compared to a control group, in which the improvement was greater in the group that performed hydrogymnastics. The improvement in exercise capacity measured by VO2peak in the water-training group and the land-training group was even greater than reported in previous studies examining the effects of hydrogymnastics (Caminiti idr., 2010; Cider idr., 2006; Mourot idr., 2009). This result should be explained by the fact that some authors included younger patients whose baseline VO2peak values were higher to begin with, and therefore the final improvement was smaller compared to the study by Vasić et al. (2019). Another possible explanation could be that the greater improvements are due to the specific physiology of thermoneutral immersion or to the higher intensity of training in water. Regarding specific physiology, thermoneutral immersion in water is associated with haemodynamic and peripheral responses such as increased pulse volume and ejection fraction, reduced heart rate, marked systemic, pulmonary and coronary vasodilatation, enhanced neurohumoral adaptations, reduced renin, angiotensin II and aldosterone activity, reduced sympathetic tone, increased atrial natriuretic peptide release associated with improvements in cardiac muscle efficiency and endurance (Vasić et al. , 2019). Mechanisms for improved aerobic endurance quality have been attributed to increased venoarterial difference and better oxidative enzyme activity (Barbosa et al. , 2009).

The assessment of left ventricular (LV) function is very important in the management of patients with heart failure. The objectification of impaired LV function is one of the recommended criteria for the diagnosis of heart failure. The most important parameter for the assessment of systolic function is left ventricular ejection fraction (LVEF) (Tretjak & Koželj, 2004).

Teffaha et al. (2011a) measured left ventricular systolic function, cardiorespiratory function, haemodynamic variables and autonomic nerve activity in a 3-week study. The study included 24 male CAD patients with preserved left ventricular function and 24 male CHF patients with stable clinical status who were randomised into a group. The latter group performed the training programme entirely on land or partially in water and the latter group performed the programme only on land. At rest, significant improvement was observed in the heart failure patients after both types of rehabilitation, with increases in left ventricular stroke volume and left ventricular ejection fraction but no improvement in left ventricular end-diastolic diameter, heart rate and diastolic arterial pressure. A significant increase in peak VO2 and heart rate was observed in all subjects, but no changes in autonomic nervous system function, probably due to the too short 3-week study (Teffaha et al., 2011a). Fiogbé et al. (2018) showed the opposite in a 4-month study. They focused on autonomic dysfunction of the heart, which is a characteristic change in CAD patients that is closely associated with adverse outcomes. They divided 26 CAD patients into groups. The first performed aerobic exercise in water, and the second was a control. The main findings of this study are that the proposed hydrogymnastics model improved cardiac autonomic regulation but failed to reduce body fat percentage (Fiogbé et al., 2018a).

Immersion can cause adverse cardiovascular events, including arrhythmias in patients with damaged heart muscle or patients with heart failure. The aim of the 8-week study conducted by Korzeniowska-Kubacka et al. (2016) was to assess the effect of hydrogymnastics, in moderately cold water, 28-30 °C, on arrhythmias and exercise capacity in stable CAD patients with preserved left ventricular function. All participants improved exercise capacity, but of concern is the fact that hydrogymnastics when compared with cardiopulmonary exercise testing, resulted in ventricular extrasystoles in 58% of participants and supraventricular extrasystoles in 62%. A possible explanation for this effect is that immersion in water causes a greater venous return and a greater preload on the right and left heart. This shift of blood volume into the thoracic cavity also overloads the atria. Atrial overload is thus a possible arrhythmogenic factor (Korzeniowska-Kubacka et al., 2016). Another possible explanation for the occurrence of extrasystoles is the temperature of the water. Schmid et al. (2009) performed a hydrogymnastics programme at a water temperature of 22°C, which resulted in a significant increase in ventricular extrasystoles in patients with CHF, however these phenomena were not observed in patients with CAD (Schmid idr., 2009).

Biomarkers are important in the diagnosis, risk stratification and treatment of patients with heart failure. NT-proBNP is the N-terminal fragment of pro B-type natriuretic peptide, which is an early marker of heart failure, in particular systolic and diastolic left ventricular dysfunction. It is used to detect milder forms of heart failure in at-risk individuals or to track the course of the disease and monitor treatment. The synthesis and release of BNP is triggered by stretching of cardiac muscle cells and overload of cardiac volume. It is secreted by the left ventricular wall in an amount roughly proportional to the wall tension, making NT-proBNP an important independent predictor of early death in patients with acute coronary syndrome (SYNLAB Slovenija - NT-proBNP, b. d.). The effect of thermoneutral water immersion on NT-proBNP in heart failure patients with ischaemic aetiology was studied by Shah et al. (2019). He reported that no significant differences in NT-proBNP levels were observed before or after immersion in thermoneutral water (Shah idr., 2019). Similarly, NT-proBNP levels did not change in studies by Municinó et al. (2006) and Sveälv et al. (2012). The opposite findings were reported by Vasic et al. (2019), who found a significant reduction in plasma NT-proBNP levels of 22.2 % in a group of patients who performed hydrogymnastics. The reduced percentage improvement, compared with other studies, was attributed to the fact that the land exercise participants were older, with lower functional capacity and baseline higher NT-proBNP levels (Vasić, 2021).

Most studies have shown comparable safety and efficiency of hydrogymnastics with an exception to swimming, with land-based exercise for improving physical performance (Cider idr., 2003; Korzeniowska-Kubacka idr., 2016; Lee idr., 2017; Magder idr., 1981; Mourot idr., 2009; Park idr., 1999; Teffaha idr., 2011; Tokmakidis idr., 2008; Vasić idr., 2019), better regulated blood pressure, reduction in peripheral vascular resistance (Schmid et al., 2009), and adaptations in body composition and muscle strength (Volaklis et al., 2007). Hydrogymnastics has been shown to effectively increase basal NO levels in coronary patients, and it is hypothesised that this may be associated with an improvement in endothelial function (Mourot et al., 2008; Vasić et al., 2019). Previous research on the impact of hydrogymnastics in coronary patients is sparse compared to different modes of land-based exercise (Schmid et al., 2007; Teffaha et al., 2011a; Vasić et al., 2019; Volaklis et al., 2007).

5. CONCLUSIONS

Rehabilitation of a cardiac patient is complex, challenging and focused individually. The term cardiac patient is generic and includes a variety of cardiovascular diseases. In addition, there are many individual differences between them and therefore associated diseases which must also be taken into account. Water is a medium that does not represent the natural human environment, therefore the physiological responses to exercise in water are different from those on land. In addition to the underlying disease, the patient's current clinical condition and functional capacity should also be taken into account. Internists and cardiologists do allow the option of water exercise for those who have had 6 months or more since the acute coronary event to achieve 5 METs on exercise stress testing to achieve a left ventricular ejection fraction of more than 50 %. Due to all these factors, it can be concluded that it is only suitable for stable cardiac patients, who should, however, urgently consult a cardiologist and have the appropriate measurements taken before entering the water.

Further research is needed with a larger number of diagnostically different subjects such as testing of long-term effects, direct comparisons between different modes of hydrogymnastics. More uniform measurement tools and a larger number of research is needed. Future research should include more representative samples to identify feasible and uniform hydrogymnastics protocols. More data on different cardiac diagnoses would help doctors and physiotherapists understand how different cardiac patients react to water exercise and how to provide a more effective exercise prescription tailored to individual heart conditions.

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