Systematic Review

Water-based exercise in chronic obstructive pulmonary disease

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Background: Water-based exercise has long been used as a therapeutic modality for the treatment of a wide variety of health conditions. However, head out of water immersion (HOWI) was previously thought to be detrimental to the respiratory system and was not recommended for people with chronic obstructive pulmonary disease (COPD). Recent research has provided evidence to the contrary. In fact, HOWI and physical exercise training in water may improve exercise capacity and health-related quality of life in people with COPD.

Objective: To review the physiological effects of HOWI and the safety and efficacy of water-based exercise for people with COPD.

Major findings: HOWI and exercise in water can be performed safely without any adverse events and with maintenance of oxygen saturation even in those with severe COPD. Evidence is beginning to emerge on the beneficial effects of water-based exercise training on exercise capacity and quality of life in COPD although further high quality research is required.

Conclusion: Water-based exercise is safe and provides a promising treatment approach which may be used to assist in the management of COPD.

Keywords: Water-based exercise training, COPD, Physiology of water immersion

Water-based exercise is used in the treatment of a wide variety of health conditions and has been recognized as a beneficial therapy for, among others, osteoarthritis,[1] rheumatoid arthritis,[2] and stroke.[3] For people with chronic obstructive pulmonary disease (COPD), the use of water-based therapy has only been considered as a possible treatment option in the last decade. Land-based exercise training, as part of integrated pulmonary rehabilitation, is advocated as one of the most effective strategies for the management of COPD and has been shown to improve exercise capacity and quality of life.[4] However, many people referred to pulmonary rehabilitation with COPD are in the older-age category and may have physical co-morbid conditions including neurological, orthopaedic, or musculoskeletal conditions which co-exist with COPD. The rates of obesity as a co-morbid condition in people with COPD are also increasing.[5,6] Consequently, participation in traditional land-based exercise training programs for people with co-morbid conditions may be difficult. The challenge is to offer people with COPD who have co-morbidities or who are unable to access existing pulmonary rehabilitation programs an alternative form of exercise training in which they can engage and from which they can reap the known benefits of exercise training. One such form of exercise which is emerging is water-based exercise training.

In the past, head out of water immersion (HOWI) was thought to be detrimental to the respiratory system[7] and hence was not advocated for people with COPD. However, recent research has challenged this notion.

Methods

MEDLINE, Scopus, Web of Science, CINAHL, AMED, EMBASE, and PEDro databases were searched in May 2010 for relevant articles. Search terms are given in Table 1. The inclusion criteria were randomized or quasi-randomized controlled trials which included: (1) people with COPD of any age or disease severity, as long as a formal diagnosis of COPD was based on acceptable criteria such as pulmonary function tests; and (2) water-based exercise training programs of at least 4 weeks duration compared to other forms of exercise training or no exercise training. The exclusion criteria were:

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DOI 10.1179/1743288X10Y.0000000024

Table 1 Water-based exercise training search strategy

#	Search terms	Results
1	'Lung diseases, obstructive' or 'pulmonary disease, chronic obstructive' or 'COPD' or 'emphysema' or 'chronic bronchitis' or 'chronic obstructive airway disease' or 'COAD' or 'chronic airway limitation' or 'CAL'	48 128
2	'Water*' or 'aqua*' or 'bath' or 'hydrotherapy' or 'immers*'	487 607
3	#1 and #2	682
4	Limited #3 to relevant studies	4
5	Limited #4 to randomized controlled trials and quasi-randomized controlled trials	1

(1) studies including participants with other respiratory conditions such as asthma, bronchiectasis, interstitial lung disease, and cystic fibrosis; and (2) studies written in languages other than English.

Results

The abstracts of 682 articles were identified during an electronic search on MEDLINE. Four studies were selected as relevant to the review, with only one study being a randomized or quasi-randomized controlled trial. A repetition of the search on CINAHL, AMED, EMBASE, Scopus, Web of Science, and PEDro revealed one further article which reported additional results from the quasi-randomized controlled trial found on MEDLINE. A total of one study examined the effects of water-based exercise training in a quasi-randomized controlled trial; however, results were presented in two separate papers (Table 2). In addition, one study examined the physiological effects of water-based exercise in COPD. Thus, a total of five relevant papers were identified for review.

Physiological effects of HOWI on the respiratory and cardiac systems

Healthy subjects

In healthy subjects, hydrostatic pressure can both directly and indirectly influence the respiratory system in the upright position in neck-deep water.[8] Directly, there is a restriction in chest expansion when inspiratory muscle contractions are unable to equal or overcome the force of hydrostatic pressure.[9] There is also an imbalance in intrapulmonary and extrapulmonary or hydrostatic pressure across the rib cage which can cause a decrease in lung volumes including vital capacity, total lung capacity, functional residual capacity, and expiratory reserve volume.[10] Vital capacity is decreased by up to 10% during immersion[8] and residual volume is reduced by 46%.[9] Because the lung volume decreases, airways resistance increases by 58%.[9]

Indirectly, hydrostatic pressure causes compression of the abdomen, resulting in a cephalad movement of the diaphragm which restricts space in the thoracic cavity. This, combined with the hydrostatic pressure on the rib cage, contributes to the reduction in lung volumes and may also cause compression of airways.[11] The diaphragm muscle length also changes with the cephalad displacement and may alter its force of contraction.[9]

In neck deep water, hydrostatic pressure causes a redistribution of blood from the lower limbs up to the cardiothoracic space, resulting in relative central hypervolaemia.[10] Central blood volume can increase by up to 700 ml which causes an increase in venous return.[10] This is termed central vascular engorgement and leads to an increase in stroke volume of up to 50%,[12] and a 34% increase in cardiac output[10] without a significant change in heart rate. It is

Table 2 Water-based exercise training study

			Water-based and land-based exercise training					Control
Study	Participants	Study design	Mode	Duration	Frequency	Exercise time/session	Exercise intensity	Intervention
Wadell *et al.* (2004);[20] Wadell *et al.* (2005)[21]	Total n=43; mean percent predicted forced expiratory volume in one second (FEV_1) (SD)=53 (12)	Quasi-randomized controlled trial	Supervised outpatient aerobic group training	12 weeks	Three times/week	45 minutes	Mean heart rate 80–100% of peak heart rate measured on a maximal cycle ergometry test; Borg dyspnoea score of 5; Borg rating of perceived exertion score of 15	n=13; no intervention

hypothesized that central vascular engorgement influences lung volumes by reducing lung compliance and promoting gas trapping via pulmonary vascular engorgement which narrows the airways.[13]

COPD

Only one study has evaluated the physiological effects of HOWI on people with COPD. Perk *et al.*[14] compared cardiorespiratory parameters at rest on land and in 32°C water in 20 stable non-hypoxaemic patients with COPD. They found no significant difference in resting heart rate, breathing frequency, or oxygen saturation when submersed in the seated position with the water surface reaching the level of the jugular fossa. Significant reductions in systolic and diastolic blood pressure and a significant reduction in lung function parameters were found with decreases in vital capacity by 12%, forced expiratory volume in one second (FEV1) by 14%, and peak expiratory flow by 18%. The authors reported that some patients experienced slight initial dyspnoea and fear when submerged in the water but this subsided after the first few minutes. No acute respiratory attacks or other adverse events were observed.

Physiological responses to exercise in water

Healthy subjects

The physiological response to water-based exercise in healthy subjects has been investigated during many different types of water exercise. It is important to note that oxygen consumption (V_{O2}) and heart rate are influenced by the depth and temperature of the water, exercise mode, and speed.[15] During aquatic treadmill running, V_{O2} was three times greater at a given speed of ambulation in water than on land.[16] Walking on treadmills underwater[17] and aerobic exercise in chest-deep water[18] resulted in significantly higher V_{O2} compared to similar exercise on land.

With regard to heart rate response, the general trend found across all studies was a lower average heart rate (an average of 10 beats/minute less) at a given submaximal V_{O2} when exercising in water compared to land.[16] Higher ratings of perceived exertion measured by the Borg scale were also found in water exercise. In suspended deep water running, the perceived level of exertion was higher for a given heart rate compared to treadmill running on land.[17] Minute ventilation and breathing frequency have also been found to be significantly greater during treadmill running in water compared to treadmill running on land at an equivalent V_{O2}.[19]

COPD

Only one study has evaluated the physiological responses to exercise in water of people with COPD.[14] In a comparison of land and water exercise, 20 stable non-hypoxaemic patients with COPD completed three periods of submaximal (75% of maximal heart rate) dynamic arm and upper body exercise, each lasting 3 minutes followed by 2 minutes rest.[14] The exercises were performed in the seated position with the water surface at the level of the jugular fossa. The exercises and workload were specifically chosen to be comparable on land and in water. Equivalence was achieved by using slow movements in the water to minimize the influence of water resistance and also using a metronome to set the pace. All patients were able to reach their target heart rates. Borg scale ratings of perceived effort and dyspnoea were higher during the water exercise. There was no difference between the land and water exercise in heart rate response and no clinically relevant difference in oxygen saturation. All subjects were able to complete the water exercise session without discomfort. No exercise had to be discontinued due to low oxygen saturation levels, dyspnoea, or any other reason. The authors concluded that despite lung function restriction in water, all patients (even those with FEV_1<35% predicted) could perform exercise in water safely without clinically relevant desaturation, arrhythmias, or discomfort.

Effects of exercise training in water in COPD

Water-based exercise training in people with COPD is a relatively new concept and as such there is minimal high quality evidence of its efficacy. Only two prospective papers have investigated the effect of water-based exercise training on people with COPD.[20,21] Both papers refer to the same study but report different outcomes. In this quasi-randomized study, 30 people with moderate to severe COPD exercised either in water or on land.[20] In both groups, high-intensity group exercise was performed for 45 minutes, three times per week for 12 weeks, at a mean heart rate of 80–100% of peak heart rate measured on a maximal cycle ergometer test. The water-based program was held in a 33–34°C pool and consisted of a 9-minute warm-up and flexibility exercise component followed by alternating 4 minutes of endurance exercises and 3 minutes of strength exercises for the legs, arms, and torso. The session concluded with flexibility, stretching, and cool-down exercises for 15 minutes. The water-based exercise group increased their walking endurance significantly more than the land-based exercise group. Health-related quality of life according to the total score in the St George's Respiratory Questionnaire remained constant in both groups. However, the water-based exercise group improved their activity subscore of the St George's Respiratory Questionnaire and their physical component summary score of the Short Form 36 significantly more than the land-based exercise group. This study effectively showed that with comparable exercise intensity, group exercise in water had additional benefits in terms of walking endurance and quality of life compared to group exercise on land. In an additional paper,[21] the authors reported other outcomes from the same study. An improvement in maximal knee flexion strength was found in both training groups; however, knee extension strength was only improved in the land-based training group. Knee extension muscle endurance was also measured but 64% of all subjects were unable to complete the muscle endurance test at baseline. In those subjects who were able to complete the test, no change was seen in muscle endurance after training either within or between groups.

Other non-randomized trials investigating the effects of exercise training in water on people with COPD include an observational study[22] and a retrospective study.[23] In a single group observational study investigating swimming pool-based exercise as pulmonary rehabilitation, 101 patients with COPD identified from a general practice computer disease register were invited by letter to join the trial.[22] Twenty-four patients expressed an interest but only 16 participants started the water-based pulmonary rehabilitation program. The program consisted of supervised individual exercises in 29°C water for half an hour, twice a week for 6 weeks. The exercise session consisted of resistance exercises using elevation and movement against water and endurance exercises for both the upper and lower limbs, adapted to the individual participant's capacity. Exercise intensity was not reported. There were significant improvements in the dyspnoea score of the Chronic Respiratory Disease Questionnaire and in incremental shuttle walk distance.

One further study examining water-based pulmonary rehabilitation used a retrospective design. The records from 20 people with COPD who completed a water-based pulmonary rehabilitation program were matched (based on age, sex, FEV_1 within 0.20 l/minute, and percent predicted FEV_1) with records from 20 people with COPD who completed a land-based program.[23] Water temperature was not reported. Endurance and strength training was performed for 90 minutes, three times per week for 6 weeks. The water-based program included guided lane walking forwards, backwards, and sideways and intervals of marching in place, hip abduction/adduction and trunk rotation with knee extension. The resistance training component used flotation devices such as kickboards and noodles for upper and lower extremity exercises such as knee extension, squats, stair climbing, hamstring curls, and shoulder flexion and abduction. The endurance component for both groups was performed at 60–80% of predicted maximum heart rate and Borg dyspnoea rating of 11–14 (6–20 scale). The land-based strength training program was progressed over 6 weeks to train up to 100% of 6-repetition maximum strength test with the water-based strength training program progressed by encouraging participants to increase effort and speed to increase water turbulence and thus increase resistance. While both groups significantly improved in all outcome measurements, no difference was found between the land- and water-based exercise groups in terms of functional exercise capacity, strength, or quality of life.

Discussion

Despite hydrostatic pressure in HOWI causing a reduction in lung function, the limited evidence presented indicates that HOWI is safe and well tolerated in COPD. People with COPD often have an increased functional residual capacity and residual volume due to pathological lung changes. Symptomatically these people have increased difficulty breathing and heightened sense of dyspnoea. It has been postulated that the reduction in these lung volumes during HOWI may assist with decreasing the sensation of dyspnoea and assist with the completion of exercise in water.[20]

No studies have evaluated the relative effects of immersion of the thorax and abdomen to different water depths. Water immersion could potentially influence diaphragm function. Due to hyperinflation the diaphragm in people with moderate to severe COPD is reduced in surface area, length, and area of apposition[24] compared to normal, resulting in alterations in the diaphragm mechanics. Immersion to the umbilical level may not increase abdominal hydrostatic pressure sufficiently to affect any change in diaphragm function. However, it is conceivable that immersion to the xiphisternal level could increase the hydrostatic pressure on the abdomen such that the diaphragm function may be potentiated in a similar manner to that which occurs in the lean forward position.[25] Immersion to the sternal notch could cause chest wall restriction, as indicated by Perk *et al.*[14] thus negating the positive effect on diaphragm function that may occur when immersed to the level of the xiphisternum. Therefore, the optimal water depth at which exercises should be performed needs to be established. A graduated pool depth will ensure that appropriate water depth is available for varying participant heights.

To date, no studies have reported the acceptability of the aquatic environment for people with COPD. The effect of ambient air and water temperature and humidity in the aquatic environment on people with COPD is unknown. Pool chemistry is also important as some people with COPD report an increase in their symptom of breathlessness when exposed to chemical fumes such as chlorine. In fact, chlorine exposure has been associated with irritation and potential damage to lung tissue.[26,27] These parameters need to be considered when contemplating water-based exercise in this population.

There are some precautions which should also be considered when using the aquatic environment for exercise training in people with COPD.[28] Appropriate screening prior to commencement of water exercise is important to determine shortness of breath at rest and on exertion, water confidence, and presence of anxiety. Further considerations include: access to pool area and pool; change, shower and toilet facilities; and location, and availability of emergency equipment. During treatment sessions, the position in the water and the depth chosen should be considered carefully, medication should be poolside, and people with COPD should be warned that shortness of breath may initially increase. Well-supervised exercise of short duration and appropriate rests would be recommended initially. High dependency clients, including oxygen therapy, may require increased assistance in the pool and adequate medical back-up as required. Oxygen delivery devices should be safely secured on the pool deck and pulse oximetry may be considered to monitor oxygen saturation levels in response to immersion and exercise. Finally, infection control officers should be liaised with regarding infectious conditions and suitability for entering the aquatic environment.

In people with COPD, there is inconclusive evidence that water-based exercise training produces comparable outcomes to land-based exercise training. Although water-based exercise training has been shown to provide additional advantages in terms of improvements in peak and endurance walking capacity and self-reported quality of life compared to land-based training in a quasi-randomized trial,[20] these positive benefits were not consistently shown in the observational and retrospective trials.[22,23] The lack of conclusive findings may relate to both the quality of the studies reviewed (i.e. poor methodology and design) and the quality of the exercise prescription and training. Limited details are given in each of the studies on the specific exercises used. For example, the lack of change in knee extensor strength and endurance found in the water exercise group in the paper by Wadell *et al.*[21] may be related to the nature of the exercises in water and whether equipment or buoyancy was utilized for strength training and exercise progression.

The inconclusive evidence for benefits of water-based compared to land-based exercise training in COPD may also relate to the selection of participants in the studies. All studies examining the effects of exercise in water on people with COPD cited the presence of co-morbid health conditions as a reason for considering water-based exercise as an alternative to the traditional land-based exercise programs currently available as part of comprehensive pulmonary rehabilitation. However, each study excluded subjects with the presence of co-morbid conditions that could have interfered with exercise training or performance. Exercise training in water has been shown to be effective in many different health conditions including joint arthroplasty,[29] fibromyalgia,[30] and chronic low back pain.[31] Thus, the presence of a physical co-morbid condition should not be a reason for exclusion from a water-based exercise training program. It should, in fact, be a compelling reason to warrant the water environment as the preferred mode of exercise training especially when the co-morbid condition may limit participation in land-based exercise training or impair the ability to exercise at high intensities for people with COPD.

Finally, with a growing COPD population, water-based therapy may be a viable and suitable alternative to gym-based exercise training to engage people with COPD in physical training. The ability to safely achieve strength and endurance training with or without equipment further makes water-based exercise an attractive alternative.

Conclusions

HOWI and exercise in water is feasible, safe, and potentially beneficial in people with COPD; however, research on water-based exercise training in COPD remains limited. Further rigorous high quality randomized controlled trials with appropriate sample size in people with COPD are needed to establish, with certainty, the improvements in exercise capacity and quality of life that have been found in water-based exercise training studies to date. Other relevant outcomes, such as the effects of water-based training on respiratory muscle strength and psychosocial factors, also need to be examined. Additionally, evaluating the effects of water-based exercise in a comprehensive pulmonary rehabilitation program incorporating self-management education and training is warranted. Long-term follow-up studies would also be useful to determine the maintenance effects of repeated water-based exercise training. The most effective water depth to perform exercise training to maximize respiratory function also needs to be established as well as the most appropriate aquatic environment ambient air and water temperature and humidity. Finally, future studies should also include (not exclude) the wider range of people with COPD presenting to exercise training programs with co-morbid physical conditions which may impact their ability to perform exercise training.

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