EXPLORING THE EFFECTS OF COLD-WATER SWIMMING ON OBESE POPULATION: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Obesity is a life-threatening condition linked to various diseases in all ages. Most common interventions focus on physical activity though there are some drawbacks limiting peoples' participation in exercise. Swimming targets these limitations offering promising results to people who wish to improve their lifestyle.

Objectives: The aim of this review is it to investigate the effects cold water can have on the obese population. This will be done by examining the physiological effects of swimming, understanding if different water temperatures can result in different outcomes and finding any other benefits that come along with swimming exercise.

Search Strategy: PubMed, EbscoHost and Google Scholar are used as search engines to find the appropriate papers using the words obese, overweight, swim, aquatics, water immersion. A systematic review summarises the findings of primary research papers. This review is based according to the PICO guidelines and all the selected papers are evaluated using the CASP tool. A meta-synthesis summarises the results of the papers.

Results: Results indicated that swimming helps people lose weight while providing additional benefits such as decreasing joint pain in people suffering from osteoarthritis. Furthermore, positive results are seen in anthropometric measures, physiological responses, and body composition.

Conclusions: It is concluded that water-based exercise can prove an effective intervention for obese people wishing to lose weight. Results were seen from different protocols and water temperature was difficult to monitor. Future research should use the same exercise design in various water temperatures to fully understand the differences in the results.

Key words: *Swimming, Obesity, Temperature, Cold, Systematic Review*

BACKGROUND

Obesity is a condition of additional and unnecessary body fat (Pozza and Isidori, 2018). While there are many reasons lying behind people being overweight, excessive mass is agreed to be an imbalance between energy intake and energy expenditure in favour of the prior (Vandevijvere et al., 2015). Sedentary lifestyle leads to lower caloric expenditure and promotes weight gain. Studies suggest that regular physical activity can help maintain and sustain a desirable body weight and composition by reversing this imbalance and favouring caloric expenditure provided that the volume, intensity and frequency of exercise is high (Bouchard, Depres and Tremblay, 1993). Exercise may also offer additional benefits to people who are overweight such as increased cardiorespiratory fitness and reduced cardiovascular disease risk factors (Segal, Pi-Sunyer, 1989).

In 1998, Horton and Hill rose this debate whether a sedentary lifestyle is a cause of obesity or a consequence. This statement can be true both ways. Sedentary lifestyle as explained above leads to weight gain due to the energy imbalance created when being physical inactive. However, because obesity is a product of various reasons such as parenthood and food choices, many overweight people might have *grown* to a state where being active is not an easy option. Extreme obesity, according to Unick et al. (2013), is one of the major limitations of inactivity and causes of osteoarthritis. In these cases, mixed interventions are used to maximise results by incorporating nutritional interventions to reduce caloric intake, and lifestyle-behavioural interventions to support and educate individuals before moving on to physical active protocols.

The second major limitation is joint pain, commonly known as osteoarthritis. Osteoarthritis is mostly seen in overweight people (Okay et al., 2009) and it affects mostly the lower limps such as the hips and knees (Bennell and Hinman, 2011) resulting in pain, stiffness, swelling and joint and muscle weaknesses (Vincent et al., 2012). It is caused by previous knee injuries, knee-straining work, aging (Miranda et al., 2002), malalignment, genetic and ethnic predispositions, muscle weakness and extra loading such as weight and specific physical activities (Felson, 2004). Furthermore, pain can also manifest in non-loadbearing joints such as the lumbar spine causing back pain (Vincent et al., 2012) and reducing the quality of people's lives.

Studies suggest that moderate exercise is a beneficial non-pharmacological approach that prevents osteoarthritis and stops its acceleration in people who already suffer from it, provided injury does not occur (Bosomworth, 2009; Bennell and Hinman, 2011). Specifically, in his study, Bosomworth tested whether exercise would actually help or hinder people with osteoarthritis and found that the participants not only improved physical functioning but also resulted in less pain and disability. Vincent et al (2012) explains that this is due to the reduction of body weight because of exercise, which lowers the mechanical and inflammatory stressors on load bearing joints.

Extreme obesity, hip and knee bearing movements as well as back pain are factors that drive people to be physical active or inactive. There is a wide variety of methods for weight loss including appropriate nutrition, medications, bariatric surgery and exercise to lower people's weight and increase physical function without pain (Vincent et al., 2012). However, exercise is preferred amongst the later, and more specifically aquatic practice (Bosomworth, 2009; Bennell and Hinman, 2011) since some physical activities are a cause of osteoarthritis themselves (Felson, 2004). Aquatic training immediately tackles the hip and knee bearing barriers and offer a great alternative to individuals who wish to lose weight and already suffer from osteoarthritis but want to be physical active. The limited evidence for the benefits of swimming on obesity is a certain downside. However, with the continuous rising numbers of obese people around the world, a new intervention is undoubtedly a necessity. Therefore, further research around this area would stretch what is already known about swimming and might prove it to be a more effective intervention by a; targeting a wider population, that is obese people who also have joint discomfort and back pain, b; using this type of practise as a foundation before moving on to more load-bearing training and c; resulting in similar or better outcomes.

Diverse temperatures can make the body respond in different ways. Warm environments cause blood flow and core temperature to increase together with sweat rates that enhance cooling (Hoffman, 2014). Additionally, a study by Sramek et al. (2000) showed that heart rate decreased, as well as systolic and diastolic pressures, reducing the amount of effort the heart must do to move the blood around the body (Becker et al., 2009). On the other hand, cold environments can result in heat loss (Stocks et al., 2004) while minimizing the decline in core temperature (McArdle, Katch and Katch, 2010). Metabolic rate is increased due to shivering in order to produce heat, and higher oxygen consumption is required (McArdle, Katch and Katch, 2010). Because of that, heart rate is increased making the heart work faster (McArdle, Katch and Katch, 2010) to provide the body with oxygen. This results in increasing the systolic and diastolic pressures (Becker et al., 2009). Furthermore, prolonged hours of being exposed to a cold environment may also increase metabolic rates during rest (McArdle, Katch and Katch, 2010).

In addition to the above, cold and hot exposure affect the contractile properties of the musculoskeletal system (Kubo, Kanehisa and Fukunaga, 2005). Due to this, cold water immersion is often used as a form of treatment after strenuous physical activity (Eston and Peters, 1999; White and Well, 2013). Opposed to cold treatments, methods that involve contact with warmth are not often seen due to increases in blood flow that may cause swelling in the strained areas (Gregson et al., 2011). Lastly, cases have shown that cold water swimming can have positive effects on mental health, particularly in people suffering from depression and anxiety (BBC, 2018). Even though the studies in this area are limited, Sramek et al (2000) explain that cold environments effect the sympathetic nervous system which may have additional consequences in the human body. The aim of this review is to explore the effects of cold-water exercise and the benefits these may have in the obese population.

METHODOLOGY

Search Strategy

The search strategy for the current systematic review was based on the PICO framework. This context stands for population/problem, intervention, comparison and outcome, and helps to determine the inclusion and exclusion criteria and making the research question specific (Scells, et al., 2017). The population and problem of interest involves overweight and obese adults following a water-based intervention with the key aim to lose weight. The effectiveness of these protocols was measured by comparing the participants weight, body mass index, waist circumference or physiological responses before and after they have taken part in the experiments. The magnitude of the results and any further benefits achieved from the intervention would lead to answering the research question. Only the papers following all four components of the PICO guidelines were included in the analysis. Furthermore, the temperature of the water was noted from the studies that included this information to understand whether this could be a factor in producing different results.

The electronic databases used to apply the specific search terms were PubMed for medical and health topics, EbscoHost for high quality published articles and Google Scholar for general science and scientific journals. Only primary research studies of swimming interventions on obesity were selected. The key words used for the extensive exploration include; obese, overweight, swim, aquatics and water immersion, and were applied in all three databases. Truncations were used for the words obese and swim to maximise the number of research papers in this area. The Boolean operator "and" was used to combine terms with one another and the operator "or" to get results from at least one of the similar words. Lastly, the operator "not" was applied after the results were filtered to eliminate the papers that contained any of the exclusion criteria and to reduce the number of hits. Lastly, additional papers were obtained via reference harvesting of selected studies.

The last step of the search strategy involved the removal of any duplicates found by going through the titles of the papers. Next, the abstracts were scrutinized for eligibility and the appropriate studies were examined in full. To end the search, the CASP tool was applied to assess the papers and to determine which ones to use in the analysis. According to Moher et al (2015), the best way to interpret the search process and results for a systematic review is with the Prisma-P flowchart. Hence, Figure 1 gives the detailed procedure of this pursuit.

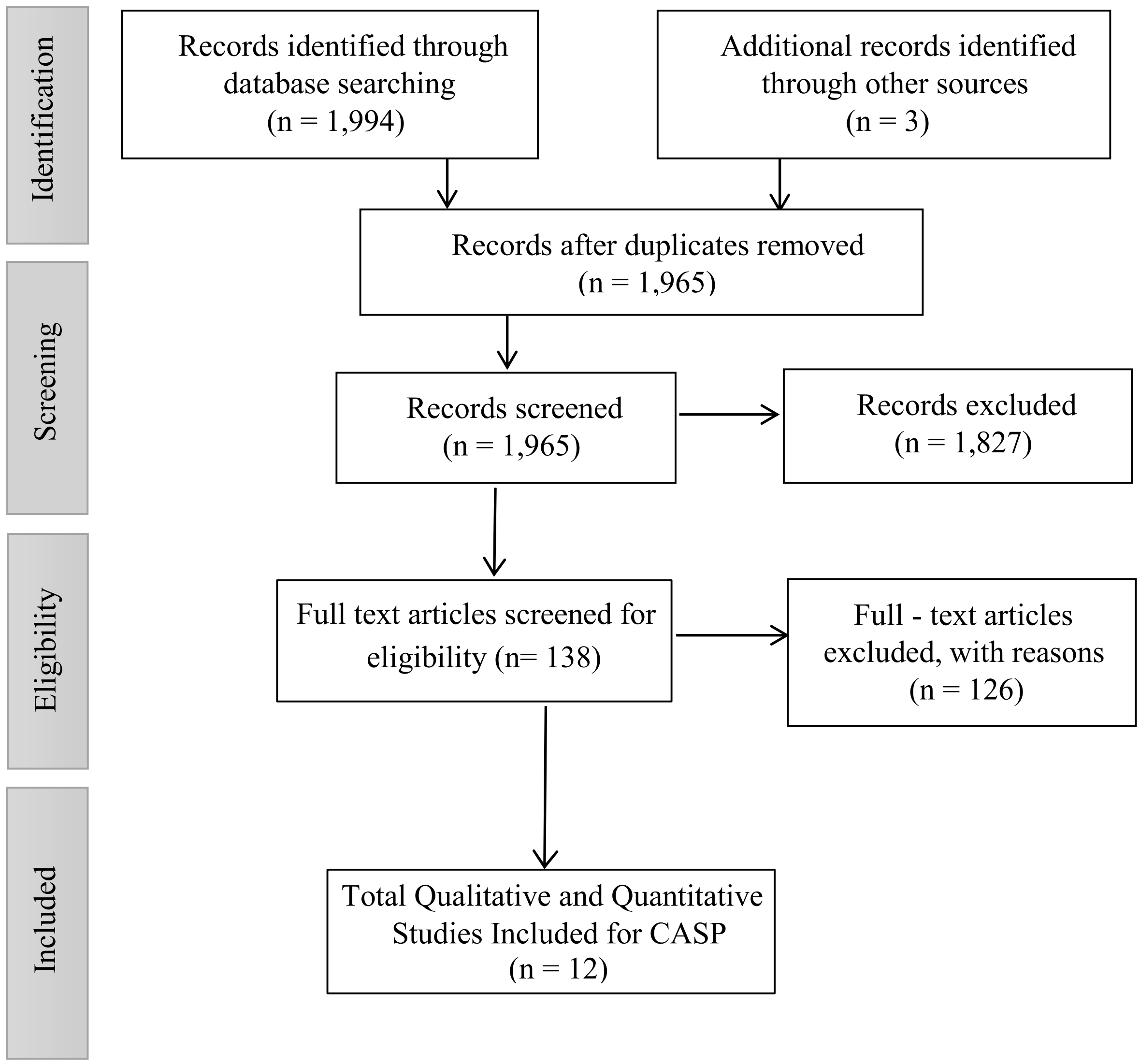

Figure 1. *The data collection process and results*

From the search in all three databases a total of 1,994 articles were gathered. A further three were found from the references of other papers. After removing all the duplicates from the list, the titles and abstracts were read to see whether they would relate to my research area and 1,827 were excluded. From the 138 fully read articles only 12 were based on the PICO framework and were eligible for evaluation using the Critical Appraisal Skills Programme tool.

Articles were removed due to the reasons:

- Involved animal subjects
- They were non-obese focused
- Water depth studies
- Not entirely focused on the desired area

- Involved unhealthy obese adults
- Involved injuries

Study Selection

The research papers were selected after applying inclusion and exclusion criteria. This was done to minimise the number of studies and to focus only on the most relevant ones. These criteria were applied for all the types of studies as well as for each of the PICO guidelines mentioned earlier. The table below gives a summary of the criteria.

Table 1. *The Inclusion and Exclusion Criteria*

	Inclusion	Exclusion
Study Type	• Primary research studies • Experimental • Cohort • Case control • Randomised control trials • Quantitative • Qualitative • 2010-2018 time-frame • English language	• Systematic reviews • Not in English language • Articles published before 2010
Population/Problem	• Obese and overweight subjects • Subjects aged 18+ • Healthy subjects (not having something related to obesity)	• Animal studies • Pregnant women • Subjects below the age of 18 • Injured subjects • Subjects with mental conditions
Intervention	Swimming and water-based exercise	• Non-water-related interventions • Interventions that include the use of dietary supplements • Interventions that include a nutritional plan
Comparison	Before and after the intervention	• Men against females • Racial comparisons • Group comparisons
Outcomes	• Weight • Body Mass Index (BMI) • Waist circumference • Physiological responses (insulin, glycogen) • Additional benefits	• Training experiences • Personal stories

The inclusion criteria were applied to make sure that all the final studies were focused on the same topic and resembled the same research area. The first step was to include only the studies that were of primary research nature such as experimental studies, cohort studies, case studies, randomised control studies which produced either quantitative and/or qualitative results. To minimise the number of papers, a timeframe of eight years was chosen and only the most recent data was studied. Additionally, only the papers written in English language were preferred. Systematic reviews were excluded due to this paper being a systematic review itself.

Following the PICO framework all the studies had to involve a population of obese and overweight individuals aged at least 18 years old. Studies with subjects below the age of 18 were excluded. The individuals had to be healthy from everything else that did not link to obesity and they should not have any injuries or mental conditions. Papers that involved pregnant women were not considered because of the complexity of the analysis. Lastly, any studies that involved animal experiments were excluded as well. The intervention of every study had to focus entirely on swimming or water immersion. Any study that included other types of exercise interventions, the use of dietary supplements or nutrition diet plans for the participants was rejected. Since this research is looking at how cold water might benefit obese and overweight people, the combination of other methods is most likely to result in false understanding. The outcomes of the papers had to include at least one of the following; weight, body mass index, waist circumference and physiological responses, specifically insulin and glycogen. Studies that mentioned any additional benefits were also included in the research to understand the magnitude swimming interventions may produce. Studies that explained experiences of different swimming protocols or personal stories were excluded as they would not offer any benefit to the current research.

Analysis

In the current research both quantitative and qualitative studies were identified. The findings are presented using meta synthesis to select, appraise, evaluate and combine the results to answer the research question. According to Walsh and Downe (2005), meta-synthesis summarises the results of different but related studies in order to deepen the understanding within an area.

RESULTS

Results of almost all papers produced positive results regarding either physiological responses or anthropometrical and functional parameters. Data including water temperatures is severely lacking. Some studies were conducted in public pools where the temperatures are most commonly over 32C^{o,} but an accurate temperature is not available. Most studies lasted for 12 weeks whereas the shortest experiment lasted one hour investigating a whole-body hyperthermia treatment by full body immersion into warm water. This was also the only study that did not produce any positive results. Specifically, physiological responses remained the same within the whole sample. The longest study was conducted by Gibas et al. (2016) which lasted six months and researched the effects of cold-water swimming in healthy people’s physiology. However, the exact temperature is not listed within their study, but they mention that the participants were swimming outdoors during the winter months. Lastly, in addition to body composition and weight improvements, studies comparing swimming protocols with other exercise designs showed that water-based exercise provided further benefits. Specifically, the studies by Jones, Meredith-Jones and Legge (2010) and Gibas et al. (2016) showed improvements in the participant’s physiology whereas the study by Yagizi et al. (2013) resulted in reduced knee pain in people suffering from osteoarthritis. Additionally, studies which compared water-based exercise to land-based exercise (Naple et al., 2017; Motimath et al, 2018) found greater results from the water training designs.

Table 2. *Summary of included studies*

Reference	Study Design	Sample Size	Duration of Study	Interven-tion	Objectives	Results	Notes
Gibas-Dorna, M., Chęcińska, Z., Korek, E., Kupsz, J., Sowińska, A. and Krauss, H., 2016. Cold water swimming beneficially modulates insulin sensitivity in middle-aged individuals. Journal of aging and physical activity, 24(4), pp.547-554.	Case-control	30 subjects aged 50 +/- 9.4	Six months	Cold water swimming at least twice a week	Changes in body composition and insulin sensitivity	Increased insulin sensitivity and improved body composition	Outdoor swim
Drenowatz, C., Hand, G., A., Shook, R., P., Jakicic, J., M., Hebert, J., R., Burgess, S. and Blair, S., N., 2014. The association between different types of exercise and energy expenditure in young nonoverweight and overweight adults. Applied Physiology, Nutrition, and Metabolism, 40(3), pp.211-217.	Cohort	417 adults (46.2% obese/overweight) aged 21 - 36	Self-reported	Variable	Examine the contribution of different types of exercise and the variability in energy expenditure and time	Swimming contributes significantly to the variability in total daily energy expenditure in obese/overweight adults	-
Yázigi, F., Espanha, M., Vieira, F., Messier, S., P., Monteiro, C. and Veloso, A., P., 2013. The PICO project: aquatic exercise for knee osteoarthritis in overweight and obese individuals. BMC *musculo-skeletal disorders,* 14(1), p.320.	Randomised control trial	50 adults aged 40 - 64	Three months, two 60-minute sessions per week	Aquatic exercise program	Control the symptoms of osteoarthritis and the participants physical activity levels and metabolic rates	Improvement of knee osteoarthritis symptoms	Water Temp: 35.5 +/- 0.5°C

Cadmus, L., I., S., A., Patrick, M., B., Maciejewski, M., L., Topolski, T., A., R., I., Belza, B., A., S., I., A. and Patrick, D., L., 2010. Community-based aquatic exercise and quality of life in persons with osteoarthritis. ***Medicine & Science in Sports & Exercise*****, 42(1), pp.8-15.**	Randomised control trial	249 adults	Twenty weeks, two sessions per week	Aquatic exercise program versus normal activity levels	Evaluate a community-based aquatic exercise in people with osteoarthritis	Aquatic exercise seems to me a good therapeutic and pragmatic exercise option of people who are obese and have osteoarthritis, BMI dropped in participants who were overweight, perceived quality of life scores improved, pain reduced	Public pool Temp
Rivas, E., Newmire, D., E., Crandall, C., G., Hooper, P., L. and Ben-Ezra, V., 2016. An acute bout of whole body passive hyperthermia increases plasma leptin but does not alter glucose or insulin responses in obese type 2 diabetics and healthy adults. ***Journal of thermal biology*****, 59, pp.26-33.**	Randomised control trial	Eighteen adults (50% obese and diabetic, and 50% healthy non-obese) aged 41.1 +/- 13.7	One hour	Whole body hyperthermia treatment via head-out hot water immersion	Testing a hyperthermic theatment to improve glucose, insulin and leptin responses	Glucose tolerance was not improved in obese and diabetic nor in healthy non-obese individuals	Water Temp: 39.4 +/- 0.4ºC
Greene, N., P., Lambert, B., S., Greene, E., S., Carbuhn, A., F., Green, J., S. and Crouse, S., F., 2010. Comparative efficacy of water and land treadmill training for overweight or obese adults. ***Medicine & Science in Sports & Exercise,*** **41(9), pp.1808-1815.**	Randomised control trial	Fifty-seven obese adults (25 men and 32 women)	Twelve weeks	Exercise x3/week either on an underwater treadmill or on land	Compare changes in fitness and body composition	Both methods improved fitness and body composition, body fat percentage, increased energy expenditure, decreased weight, but the underwater training protocol also improved leg lean muscle mass	-

Jones, L., M., Meredith-Jones, K. and Legge, M., 2010. The effect of water-based exercise on glucose and insulin response in overweight women: a pilot study. *Journal of Women's Health*, 18(10), pp.1653-1659.	Pilot study	Fifteen overweight females	Twelve weeks	Exercise x3/week for 60 minutes of moderate intensity water-based circuit training	Investigate the effectiveness on glucose and insulin responses	Improved glucose and insulin response, decreased waist circumference	Indoor pool
Colato, A., Fraga, L., Dorneles, G., Vianna, P., Chies, J., A., B. and Peres, A., 2017. Impact of aerobic water running training on peripheral immune-endocrine markers of overweight-obese women. *Science & Sports*, 32(1), pp.46-53.	Experimental	Twenty obese females aged 48.81 +/- 12.87	Twelve weeks	Aerobic water running for 70 minutes x3/ week	Evaluate the effect of water running on immune-endocrine parameters	Reduced waist circumference and improved body composition and fitness	-
Principal, D., D., 2018. Effect of Underwater Treadmill Training on Young Obese Adults.	Experimental	Fourteen obese males aged 19-35	Six weeks	25 minutes of underwater treadmill x3/week	To evaluate the effects of underwater treadmill training on anthropometrics, core strength and endurance	BMI, waist circumference and body composition improved	-
Motimath, B., Pillai, H., Motar, P. and Pradhan, S., 2018. Impact of Circuit Training Exercises on land Versus in Water in Overweight Females--A Randomized Clinical Trial. Indian *Journal of Physiotherapy & Occupational Therapy*, 12(3).	Randomised control trial	Twenty-eight females aged 19-25	n/a	n/a	To compare the effects of circuit training on obese people on land and water	BMI and waist circumference improved more in the water training group	-

Nagle, E., F., Robertson, R., J., Jakicic, J., J., Otto, A., D., Ranalli, J., R. and Chiapetta, L., B., 2017. Effects of a Combined Aquatic Exercise and Walking in Sedentary Obese Females Undergoing a Behavioral Weight-Loss Intervention. *International Journal of Aquatic Research and Education*, 1(1), p.5.	Randomised control trial	Fourty-four obese female aged 40.3 +/- 8	Sixteen weeks	X3/week	Compare swimming exercise plus walking versus only walking training on body weight	Both groups resulted in improved body weight, fitness, flexibility, body fat percentage and strength with greater results seen in the swimming and walking group	-
Rica, R., L., Carneiro, R., M., M., Serra, A., J., Rodriguez, D., Pontes Junior, F., L. and Bocalini, D., S., 2013. Effects of water-based exercise in obese women: Impact of short-term follow-up study on anthropometric, functional fitness and quality of life parameters. *Geriatrics & gerontology international*, 13(1), pp.209-214.	Experimental	Twenty-eight obese females	Twelve weeks	60 minutes x3/week	Evaluate the effects of water-based exercise on indicators of obesity	Unsuccessful in reducing anthropometric measurements but useful in functional parameters	Public pool Temp

Physiology

1. *Insulin*

Increased insulin sensitivity was found in the study of Gibas et al. (2016) who used an outdoor cold-water protocol, and in the study of Jones, Meredith-Jones and Legge (2010) who used an indoor swimming pool for their experiment. In both cases insulin sensitivity was improved following six months and six weeks respectively of training aerobically. Specifically, changes in insulin were observed from the beginning to mid-season during cold water swimming. In addition to aerobic exercise, the second study also incorporated resistance training. Insulin levels decreased by 44% at the end of the research. However, an experiment by Rivas et al. (2016) failed to show any differences in insulin sensitivity after just an hour of a hyperthermic treatment in a 39.4 +/- 0.4 C° water temperature as longer durations as mentioned above are more desirable compared to the heat of the immersion.

2. *Glucose*

The same study by Jones, Meredith-Jones and Legge produced positive results for glucose with a recording of 30.4% reduction seen after two hours of physical activity. Important to note at this point, the current group consisted of individuals with reduced glucose tolerance. On the other hand, the study by Rivas et al. (2016) did not show any differences compared to baseline figures after an hour of a full body water immersion in approximately 40C° temperature. This again confirms that longer durations yield better results compared to the actual water temperature as both interventions were conducted in warm water.

Anthropometrics

1. *Body Mass Index*

Improvements in BMI were found in the studies of Cadmus et al., (2010), Greene et al. (2010) and Nagle et al. (2017). Specifically, the study design in a public pool environment by Cadmus et al. had more positive results on the obese population (BMI<30), rather than people with BMI levels ranging from 18.5 to 30. Greene et al. compared water-based treadmill to land treadmill and BMI rates had the same magnitude of improvement from both training methods. In more detail, land treadmill improved BMI scores from 30.7 +/- 1.0 to 30.1 +/-1.0 whereas the later from 29.9 +/- 0.9 to 29.4 +/- 0.9. Lastly, Nagle et al. also compared aquatic exercise to walking and results showed an improvement in BMI by 2.6 +/- 1.2 and 2.2 +/- 1.7 respectively. A fourth study by Motimath et al. (2018) confirms these findings when comparing water circuit training to land circuit training with the later producing greater results. In conclusion, water-based training produces slightly greater results than land-based training but failure to specify the water temperature in three of the four studies makes it unable to identify the magnitude that temperature plays in the final results.

2. *Weight*

Changes in weight were observed in most of the studies showing a decrease regardless of the exercise protocol, type, exercise duration, water temperature and study length. Again, the three studies which compared water- to land-based exercise produced greater results after aquatic training.

3. *Waist Circumference*

As with weight, waist circumference measures were seen in most studies with a reduction in most cases. Changes were as high as 6% reduction after a 12-week period as seen in the study by Jones, Meredith-Jones and Legge (2010) in an indoor setting. However, the studies comparing land- to water-based protocols produced conflicting results. Motimath et al. (2018) found clinically significant results in BMI scores in a female obese population performing circuit training exercises in water compared to those training on land. On the opposite side, the study by Nagle et al. produced more favourable results towards land-based exercise with a reduction in waist circumference by 7.23 +/- 8.7cm compared to the aquatics group which decreased BMI levels by 6.63 +/- 3.2cm. Furthermore, Greene et al. produced identical results between both groups with an approximate of 3.7cm decrease in waist circumference. It is important to note here that the protocols in the three last studies varied between one another and water temperature was not indicated which otherwise may have produced more similar results to reach a conclusion regarding waist circumference.

4. Body composition

Body composition was measured by body fat percentage which improved in all the studies which included this factor. In more details, the study by Colato et al. (2017) improved body composition within an obese female population whereas Principal et al. (2018) produced positive results within an obese male population. Gibas et al. (2016) stated that obese and non-obese females tend to have greater BMI levels and less fat free mass compared to their male counterparts. However, their study, which involved swimming outdoors during the winter months, improved measures in both sexes with obese males showing greater responses. Additionally, Cadmus et al. (2010) observed changes only within the obese group compared to the control. The study by Nagle et al. produced better results for waist circumference in the land-based group compared to the aquatics group even though body composition improved equally in both land and water. Identical results were found by Greene et al. (2010) when compared land treadmill to underwater treadmill exercise design. Specifically, in their study the group training on land improved their body fat percentage from 39.4 +/- 1.8 to 36.1 +/- 1.8% whereas the group exercising on the underwater treadmill decreased their body fat percentage from 39.4 +/- 1.6 to 38.1 +/- 1.8% after a period of 12 weeks.

Additional Benefits

1. Pain

In addition to the physiological responses and the bodily changes observed, studies included *pain* as a measure in their studies. Yágizi et al. (2013) specifically tested a 3-month 35.5 +/- 0.5 C^{o} water-based intervention in a population of 56 obese individuals aiming to improve osteoarthritis symptoms. Furthermore, a study by Cadmus et al. (2010) predicted a reduction in pain scores by 0.5 in a scale of 0 to 3. They found that aquatic exercise may benefit obese people as swimming takes away the extra load from the joints and allows pain-free motion regardless of the temperature of the water.

2. Fitness Levels

Studies showed positive results in the participants' fitness levels. Improved measures of VO_2max and VO_2peak were seen in the papers of Greene et al. (2010), Rica et al. (2013), Colato et al. (2017) and Nagle et al. (2017). All protocols lasted at least 12 weeks with an additional four weeks in the study of Nagle et al. Specifically, Rica's study included exercising in a public pool with average water temperature compared to the other studies which did not specify. However, increases in strength were seen in the studies by Rica et al. and Nagle et al., and where measured by exercise repetitions. Studies comparing aquatics to walking showed improved fitness levels in both groups with water-based exercise producing more strength and improving leg lean muscle mass. However, advances in flexibility were more a result of exercising on land compared to water (Nagle et al., 2017).

3. Mental Health

In addition, benefits were seen in participants' quality of life. Specifically, Cadmus et al. (2010) collected data using the Perceived Quality of Life scale before and after their intervention program. The positive outcomes suggest that swimming is beneficial for obese people suffering also from osteoarthritis. This was linked to the fact that pain scores were decreased commencing the training period. These findings are confirmed by the study of Rica et al. (2013) who found improvements in self-reported quality of life which included physical, psychological, social and environmental aspects after a swimming intervention in a public pool. However, this may be more due to the fact that the participants interacted with individuals similar to their weight and state, and less to the temperature of the water, especially since the data is limited. These results suggest that aquatic exercise may also provide mental therapeutic properties independent of the water temperature.

DISCUSSION AND CONCLUSION

The major findings of this systematic review clearly answered two of the three research objectives that were set. The physiological responses to swimming indicated that aquatic exercise can effectively improve insulin sensitivity and glucose uptake regardless of the water temperature. According to Hoffman (2014), these hormones work hand in hand. In more detail, insulin is a glucose regulator and helps its metabolism in all the tissues within the body apart from the brain. Insulin is secreted by β-cells located within the pancreas and exercise hinders their concentration. This means that during exercise the working muscles have a greater response to glucose uptake due to the enhanced insulin sensitivity. On the other hand, the study by Rivas et al. (2014) failed to show any changes in both insulin and glycogen during a one-hour full body immersion into warm water. This is because no strain was induced in the muscles. Like this the β-cells concentration was not deterred which resulted in normal insulin circulation and thus, glucose uptake. This indicates that the time and strain of the intervention produces greater results compared to the warmth of the water.

Due to the physiological responses of exercise, differences were also seen in the anthropometric scores. Body mass index, weight, waist circumference and body composition (body fat percentage) improved in all studies regardless of exercise duration and training protocol. According to Hoffman (2014) a single bout of exercise can produce physiological changes and therefore alter hormonal response to exercise. This results in muscles working more efficient and harder to produce work which leads to greater energy expenditure. According to McArdle, Katch and Katch (2010), the thermic effect of physical activity is one of the three factors impacting total daily energy expenditure (TDEE). Furthermore, consistent physical activity stimulates resting metabolism resulting in more calories burned during rest periods. This happens because the worked muscles tend to spend 20% more energy during inactivity compared to unworked muscles, making rest the second factor affecting TDEE. Specifically, Drenowatcz et al. (2014) and Greene et al. (2010) reported higher energy expenditures from their participants after exercise. Lastly, the third aspect that contributes in excess energy utilisation is feeding which is not discussed in this review.

In addition, the study by Gibas et al. (2016) showed greater anthropometric results of obese people when compared to lighter subjects after swimming outdoors. Based on McArdle, Katch and Katch (2010) this is because overweight individuals need to move a greater surface area. This results in greater work required and thus, greater energy expenditure. Lastly, the studies that compared land-based to water-based interventions found results favouring aquatics regardless of the protocol and temperature. Swimming uses excess energy to maintain buoyancy while using the arms and the legs to generate movement. Swimmers also must face the resistance of forces such us skin friction, wave drag, and different pressures created around their bodies which makes energy expenditure four times greater when compared to a land-based programme covering the same distance (McArdle, Katch and Katch, 2010). It is therefore concluded that TDEE is the factor affecting anthropometric measures.

In addition to the above, participants' fitness was improved which is seen in the studies calculating VO_2max, VO_2peak and strength measures. Strength is affected by pretraining history, program length and training frequency and need to provide the appropriate stimulus to the muscle to develop (Hoffman, 2014). Furthermore, Boyce et al. (2009) stated that beginners and individuals with sedentary lifestyles experience greater strength gains compared to trained people. This, in contrast with Hoffman's statement, explains why increases in the participants' strength were seen in relatively short term. Moreover, changes in cardiovascular fitness refer to the increased duration of doing exercise. According to McArdle, Katch and Katch (2010), the human body hosts fast-twitch fibres which produce short bursts of strong movements and slow-twitch fibres which are responsible for endurance. Depending on the exercise type individuals can develop either aptitude. Due to the nature of all the studies and the participants' abilities, the intervention protocols consisted of low intensity, but longer duration exercise several times a week. VO_2max values have been shown to increase by 15% to 30% within the first three months of training (Hoffman, 2014), which is what is shown in the findings irrespective of the water temperature of each intervention. This is due to the increased capillary thickness that enhances the time the oxygen spends in the working muscles, thus increasing work duration (Bassett and Howley, 2000).

Studies of Yagizi et al. (2013) and Cadmus et al. (2010) found reductions in pain in subjects suffering from osteoarthritis. As explained by the authors, swimming takes away the extra load from the working joints while timely reducing excess mass and strengthening the body. Moreover, according to Kubo, Kanehisa and Fukunaga (2005), different temperatures affect the ways the musculoskeletal system contracts to produce work. Both studies mentioned involved aquatic exercise in warm environments. Gregson et al. (2011) stated that warmth increases blood flow, thus transporting oxygen and blood to the working muscles around the joint. This drives the muscles to contract more efficiently while minimising the weight the joints need to carry.

Pain was associated with improved quality of life scores seen in the study by Cadmus et al. (2010). In addition, general mental health improved in the participants of Rica et al. (2013) who reported better physical movement. Additionally, the same study revealed that progresses in the social and environmental aspect of people's lives contributing to enhanced quality of life. Even though they have been cases showing the benefits of cold-water swimming on mental health (BBC news), this does not explain the current findings as both protocols involved swimming in public pools where the water is usually warm. However, considering the reductions in pain, Heo et al. (2010) stated that mood depends on function while function depends on pain, and pain depends on obesity levels. As weight drops, so does pain which increases functional movement and improves mental health. Additionally, the social and environmental health improvements be a result of generally positive self-evaluation. In other words, according to Taylor and Brown (1988), positive self-evaluation promotes care for self and for others, the ability to be happy, productive and creative. These can lead to adopting a healthier lifestyle, seeing changes which make people happier, interacting with others and supporting change to create an encouraging environment. Therefore, it is concluded that swimming can also prove to be a mental therapy.

In contrast to the above, there are a few limitations in this review worth to mention. The first and main limitation regards the second objective set, which was not met. This is since water temperatures were not monitored during all the studies. However, based on the findings of our analysis and knowledge about the effects of the different water temperatures on the human physiology, we can assume the following; the colder the water, the greater the results. According to Stocks et al. (2004), cold environments induce shivering to provide heat for the body. To do this, the heart works harder to provide oxygen through blood to the muscles (McArdle, Katch and Katch, 2010) which require energy. This involves the use of extra calories resulting in a greater calorific expenditure in addition to the losses from exercise alone.

Second limitation comprises of the study protocols themselves. To start with, all the studies involved different exercise methods which made it difficult to understand which intervention plan was the most effective. Even so, all the results were encouraging. Next, studies focused on specific outcomes which may have led to biased results towards other factors. Furthermore, as already mentioned, water temperatures were not precise which may have contributed to the misinterpretation or the outcomes. Lastly, while great caution was taken to select studies that did not include another intervention other than exercise, it is uncertain whether the participants followed nutritional or behavioural consultation in addition to exercise. Specifically, Nagle et al. (2017) incorporated a behavioural model with the exercise intervention making it the only mixed methods study in the analysis. Additionally, the study by Drenowatcz et al. (2014) collected the data from participants self-reports. Thus, it is unsure if the participants were honest or modified their responses to display a greater discipline and attitude.

Third, studies involved populations with various health impairments. Even though this might serve as a benefit due to the positive outcomes from this review's analysis, it also stands as a limitation. In more details, Rivas et al. (2016) involved a diabetic sample and Jones, Mereditj-Jones and Legge (2010) included people with normal and abnormal glucose intolerances. Individuals with physiological differences respond in another way towards exercise which makes the results questionable. However, overweight people usually come with these further problems, so it is useful to see the magnitude of physical activity on these populations. Furthermore, the participants in the studies of Yagizi et al. (2013) and Cadmus et al. (2010) suffered from osteoarthritis. It would be of interest to see the results of their studies if exercise was not limited by the pain created from this condition. Additionally, Drenowatch at al. (2014) compared the responses of obese to non-obese participants to exercise.

Even though this study provided greater results in favour of the obese population, the protocol might not have been strenuous enough for the non-obese people in order to see similar results. However, a more strenuous training plan may have proven to be too hard for the overweight.

Lastly, the study by Rivas et al. (2016) failed to show any positive physiological results of a one-hour hyperthermic treatment. This might be because of three reasons. Firstly, the short duration of the study design, secondly, the fact that it was just water immersion and not exercise in the water, and thirdly, the high-water temperature. Assuming it is the latter, this will confirm the previous statement of "*the colder the water, the greater the results*". However, there is a need of more experiments like this to confirm the authors' findings and provide us with further and more precise information around this topic.

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