The effect of water aerobics in adults and older adults in health-related variables.
The importance of duration and intensity parameters

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Faíl, L. B., Neiva, H. P., & Marinho, D. A. (2023). The influence of water aerobics on muscle strength and body composition. *International Congress of CIDESD 2023*. University of Trás-os-Montes and Alto Douro, Vila Real, Portugal, 12-13 October.

Resumo

A hidroginástica tem ganho popularidade, com os seus benefícios cada vez mais reconhecidos. Contudo, existem informações limitadas sobre a intensidade e duração necessárias para obter resultados ideais. Esta tese explora os efeitos de diferentes intensidades e durações da hidroginástica nas variáveis relacionadas com a saúde em adultos e idosos. Para alcançar isso, foram realizadas as seguintes etapas i) uma revisão sistemática com meta-análise sobre os efeitos dos programas aquáticos na saúde e aptidão física de adultos saudáveis e com doenças crónicas; ii) comparação entre hidroginástica de intensidade moderada e elevada (12 e 24 semanas) na força muscular, antropometria, perfil lipídico, pressão arterial (PA) e qualidade de vida (QV); iii) análise da relação entre a força muscular adquirida após hidroginástica e outros fatores, incluindo a intensidade e duração do programa, idade e variáveis basais relacionadas com a saúde; iv) análise da associação entre os resultados da PA e perfil lipídico obtidos após hidroginástica e fatores como a intensidade e duração do programa, idade e medidas iniciais relacionadas com a saúde. Os resultados indicaram que i) poucos estudos avaliaram a intensidade do exercício na hidroginástica; ii) a hidroginástica de alta intensidade foi mais eficaz que a intensidade moderada na melhoria do perfil lipídico, massa gorda, massa livre de gordura, PA diastólica e QV física; iii) ambas as durações de hidroginástica de elevada intensidade beneficiaram a PA diastólica, com maiores efeitos após 24 semanas; iv) ambos os programas melhoraram a resistência muscular após 12 e 24 semanas, com a intensidade mais elevada a relacionar-se com uma melhor resistência muscular dos membros inferiores; v) a QV psicológica melhorou após 12 semanas; vi) os valores iniciais da resistência muscular e a idade relacionaram-se com os resultados da resistência muscular dos membros superiores e da força explosiva, enquanto a composição corporal inicial se associou à força explosiva; vii) as alterações no perfil lipídico foram influenciadas pela intensidade, enquanto a PA diastólica foi afetada pela duração do programa, e os níveis iniciais de colesterol total se associaram positivamente às alterações na PA sistólica e diastólica. No geral, a hidroginástica de alta intensidade melhora o perfil lipídico, a composição corporal e a QV física em adultos e idosos. 24 semanas deste exercício a elevada intensidade também reduzem a PA diastólica. A hidroginástica aumenta a resistência muscular independentemente da intensidade e duração. Esta tese oferece informações valiosas para os instrutores de hidroginástica, recomendando estratégias para adaptar os níveis de intensidade às necessidades individuais.

Palavras-chave

Hidroginástica; intensidade; duração; aptidão física; saúde; qualidade de vida; adultos.

Resumo Alargado

Dentro das atividades aquáticas, a prática da hidroginástica tem aumentado a sua popularidade nos últimos anos. Este aumento deve-se essencialmente às particularidades do meio aquático, por facilitarem a realização de exercício físico por parte de indivíduos com baixos níveis de aptidão física, com problemas de mobilidade, com doenças crónicas, ou de atletas em recuperação de lesões. Além disso, estas características também são responsáveis por diversos benefícios reconhecidos pela comunidade científica. Contudo, a literatura ainda é escassa sobre os efeitos de diferentes intensidades e períodos de implementação da hidroginástica em diversas variáveis relacionadas com a saúde. Neste sentido, o principal objetivo desta tese foi analisar os efeitos de diferentes intensidades e durações de hidroginástica em variáveis relacionadas com a saúde em adultos e idosos. Pretendeu-se compreender o efeito das intensidades e durações de exercício na força muscular, composição corporal, pressão arterial (PA), perfil lipídico e qualidade de vida (QV), procurando desenvolver recomendações para uma prática mais efetiva da hidroginástica. Para alcançar este objetivo, foram elaborados cinco artigos científicos, especificamente uma revisão sistemática com meta-análise e quatro estudos experimentais.

Estudo 1

A revisão sistemática com meta-análise foi realizada para sintetizar e analisar os dados existentes na literatura sobre os efeitos dos programas de treino aquático (TA) em diversos parâmetros relacionados com a saúde de adultos saudáveis e adultos com doenças crónicas, de forma a desenvolver recomendações úteis para os profissionais de desporto e da saúde. Para isso, foram realizadas pesquisas em três bases de dados (PubMed, Web of Science e Scopus), procurando por ensaios clínicos randomizados e não randomizados que examinassem o efeito de TA em adultos. Foram incluídos 62 estudos, dos quais 26 envolveram apenas indivíduos saudáveis e 36 focaram-se em adultos com doenças crónicas. No grupo com adultos saudáveis, os TA foram benéficos essencialmente na força muscular, equilíbrio e aptidão cardiorrespiratória, particularmente quando realizados durante pelo menos 12 semanas, com 2 a 3 sessões por semana, com duração entre 46 a 65 minutos por sessão. Nos adultos com doenças crónicas, embora as adaptações específicas possam variar consoante a doença, pode sugerir-se que os TA melhoram principalmente o equilíbrio, a QV, a força muscular, a

dor e a qualidade da marcha, sobretudo quando realizados entre 8 a 16 semanas de treino. No geral, os TA mostraram-se eficazes quando a intenção é melhorar a saúde e a aptidão física de adultos saudáveis e adultos com doenças crónicas. Apesar destas descobertas, apenas um número limitado de estudos examinou o impacto da hidroginástica e vários estudos falharam em reportar ou monitorizar a intensidade do exercício. Assim, não existe informação suficiente para estabelecer a duração e intensidade ideais da realização de hidroginástica para alcançar os resultados desejados em adultos e idosos.

Estudo 2

Para colmatar as lacunas mencionadas na revisão, foram desenvolvidos os estudos 2 e 3. Especificamente, estes estudos compararam os efeitos da hidroginástica de intensidade moderada e elevada em vários parâmetros, incluindo a força muscular composição corporal, PA, perfil lipídico e QV em adultos e idosos. No segundo estudo, vinte e uma mulheres (65.19 ± 9.37 anos) foram divididas aleatoriamente em grupos de intensidade moderada (MIG; n=11) ou de alta intensidade (HIG; n=10). Ambos os grupos participaram em sessões de 45 minutos, duas vezes por semana, durante 12 semanas. As avaliações iniciais e pós-treino incluíram a resistência muscular, força explosiva, massa corporal, índice de massa corporal (IMC), massa gorda (MG), massa livre de gordura, triglicéridos (TG), colesterol total, PA, frequência cardíaca (FC) de repouso, a QV geral e os domínios físico, psicológico, das relações sociais e ambiental da QV. Os resultados indicaram que o HIG apresentou maiores reduções no colesterol total ($\eta_p^2 = 0.28$) e na MG ($\eta_p^2 = 0.35$), e um aumento da massa livre de gordura ($\eta_p^2 = 0{,}35$), em comparação com o MIG. O HIG também apresentou melhorias superiores nos TG ($\eta_p^2 = 0.24$) e na QV física ($\eta_p^2 = 0.19$) do que o MIG. Não foram encontradas interações significativas nas restantes variáveis. No entanto, a resistência muscular e a QV psicológica melhoraram em ambos os grupos ($p < 0.05$, $ES \geq 0.57$). O HIG foi o único grupo que apresentou uma redução da PA diastólica ($p = 0.04$, $ES = -0.71$), enquanto o MIG não apresentou alterações significativas. A força explosiva não se alterou em nenhum dos grupos. Assim, o estudo sugere que 12 semanas de hidroginástica de alta intensidade proporciona benefícios adicionais em relação à sua realização a intensidade moderada na composição corporal, perfil lipídico, PA diastólica e QV física em adultos e idosos. Além disso, ambas as intensidades são eficazes na resistência muscular e QV psicológica.

Estudo 3

No estudo 3, vinte mulheres (67.10 ± 9.08 anos) foram randomizadas em dois grupos (MIG e HIG), com cada um a realizar hidroginástica duas vezes por semana, 45 minutos por aula, durante 24 semanas. O MIG executou as aulas a intensidade moderada ($n = 10$), enquanto o HIG realizou a intensidades elevadas ($n = 10$). Os participantes foram avaliados antes e depois do programa. As avaliações incluíram a resistência muscular, força explosiva, massa corporal, IMC, MG, massa livre de gordura, TG, colesterol total, PA, FC em repouso, QV geral e os domínios físico, psicológico, das relações sociais e ambiental da QV. Os principais resultados mostram que a MG ($\eta_p^2 = 0.35$; $p = 0.01$), a massa livre de gordura ($\eta_p^2 = 0.30$; $p = 0.01$), o colesterol total ($\eta_p^2 = 0.34$; $p < 0.01$) e os TG ($\eta_p^2 = 0.24$; $p = 0.03$) melhoraram mais com o HIG do que com o MIG. Ambas as intensidades de exercício melhoraram a resistência muscular, mas apenas o HIG reduziu a PA diastólica e melhorou a QV física. No fundo, 24 semanas de hidroginástica de intensidade elevada é mais eficaz do que a hidroginástica de intensidade moderada na melhoria de certos indicadores de saúde, incluindo a composição corporal, o perfil lipídico, a PA diastólica e a QV física. Além disso, realizar hidroginástica a intensidade moderada e elevada melhora a resistência muscular.

Estudo 4

Conhecendo-se o efeito da hidroginástica realizada a diferentes intensidades e consoante a duração do programa, tornou-se essencial determinar se os resultados alcançados se deveram exclusivamente à intensidade e/ou duração do exercício, ou também a outros fatores. Neste sentido, os estudos 4 e 5 foram realizados, através da análise dos dados referentes aos estudos 2 e 3 desta tese. O quarto estudo procurou verificar se a força muscular após um programa de hidroginástica está relacionada com a intensidade e duração do programa, com a idade do participante, ou com os valores basais de força muscular, da composição corporal e da QV geral. Participaram um total de quarenta e uma mulheres. Destas, vinte e uma mulheres foram aleatoriamente atribuídas ao MIG ($n = 11$) ou ao HIG ($n = 10$) e praticaram hidroginástica durante 12 semanas. Além disso, vinte participantes completaram 24 semanas de hidroginástica, 10 no MIG e 10 no HIG. As variáveis foram analisadas antes e após a implementação do treino, nomeadamente a resistência muscular, força explosiva, IMC, MG e a QV geral. Foi utilizada a regressão linear múltipla para analisar a potencial relação dos valores das variáveis avaliadas no início do programa, da idade dos participantes, da intensidade e da duração do programa com os valores de resistência muscular e força explosiva obtidos após a hidroginástica. Os resultados indicam que a força explosiva dos membros superiores obtida após o programa foi influenciada pelos valores iniciais da força explosiva, da resistência muscular e IMC. A força explosiva dos membros inferiores alcançada após os programas de treino relacionou-se com a idade dos participantes e com os valores basais de MG, QV geral e resistência muscular dos membros inferiores. A resistência muscular dos membros superiores adquirida após a intervenção relacionou-se com a idade do participante e com os valores iniciais da resistência muscular dos membros inferiores. A resistência muscular dos membros inferiores obtida com a hidroginástica associou-se à intensidade do programa, especialmente à intensidade elevada, e ao valor basal da resistência muscular dos membros inferiores. A duração do programa não apresentou qualquer relação com a força muscular. De um modo geral, a intensidade elevada da hidroginástica é essencial para melhorar a resistência muscular dos membros inferiores de adultos e idosos. O desenvolvimento da força com a prática de hidroginástica é influenciada sobretudo pelos níveis iniciais de resistência muscular, e os programas de treino devem considerar a idade e a composição corporal inicial dos participantes. Além disso, a duração do programa não é o fator mais importante quando se pretende melhorar a resistência muscular e força explosiva.

Estudo 5

O Estudo 5 explorou a relação entre os resultados da PA e do perfil lipídico derivados de um programa de hidroginástica e fatores como a intensidade e duração do programa, a idade do participante e os seus níveis basais de PA, o perfil lipídico, medidas antropométricas, e QV geral. No total, participaram quarenta e uma mulheres. Destas, vinte e uma mulheres foram aleatoriamente atribuídas ao MIG (n = 11) ou ao HIG (n = 10) e realizaram 12 semanas de hidroginástica. Além disso, vinte participantes completaram 24 semanas de hidroginástica (10 no MIG e 10 no HIG). As variáveis foram analisadas antes e após o programa de treino, especificamente a PA sistólica e diastólica, colesterol total, TG, IMC, MG e a QV geral. Através de uma regressão linear múltipla, foi analisada a potencial relação dos valores das variáveis avaliadas no início do programa, da idade dos participantes, da intensidade e da duração do programa com os valores de PA sistólica e diastólica, colesterol total e TG alcançados após a realização de hidroginástica. Os resultados demonstram que os níveis iniciais de PA sistólica e colesterol total exerceram uma influência significativa na PA sistólica após a hidroginástica. A PA diastólica obtida após os programas demonstrou uma relação com os valores iniciais de PA diastólica, colesterol total e com a duração do programa, sobretudo após 24 semanas. Os níveis de TG atingidos após a intervenção associaram-se significativamente à intensidade do programa, particularmente à intensidade elevada, bem como aos valores iniciais de TG, PA diastólica e sistólica. A intensidade do programa, principalmente a intensidade elevada, juntamente com os níveis basais de colesterol total e IMC foram significativamente relacionados com os resultados finais do colesterol total. No geral, este estudo indica que i) os valores basais de colesterol total influenciam as respostas da PA observadas após um programa de hidroginástica; ii) a intensidade elevada da hidroginástica é relevante para determinar a melhoria no perfil lipídico; iii) e a duração de 24 semanas de hidroginástica é significativa para a PA diastólica.

Com base nos resultados apresentados nos diferentes estudos, as principais descobertas demonstraram que i) embora os programas aquáticos ofereçam benefícios para adultos saudáveis e adultos com doenças crónicas, poucos estudos examinaram os efeitos da hidroginástica, e vários estudos não reportaram ou monitorizaram a intensidade do exercício; ii) a hidroginástica realizada com elevada intensidade mostrou ser mais eficaz do que as sessões de intensidade moderada no perfil lipídico, MG, massa livre de gordura, PA diastólica e na QV física; iii) ambas as durações de hidroginástica de elevada intensidade foram benéficas para a PA diastólica, com efeito otimizado após 24 semanas; iv) ambos os programas de hidroginástica utilizados demonstraram melhorias na resistência muscular após as 12 e as 24 semanas, contudo, parece existir uma associação positiva entre os resultados da resistência muscular dos membros inferiores e a intensidade utilizada; v) o domínio psicológico da QV parece ser positivamente afetado após as 12 semanas de duração do programa de hidroginástica implementado; vi) os valores iniciais da resistência muscular e a idade dos participantes pareceram ser fatores relacionados com os resultados da resistência muscular dos membros superiores e com a força explosiva em resposta a um programa de hidroginástica. Além disso, a composição corporal inicial também está associada à força explosiva obtida após as intervenções; vii) as alterações do perfil lipídico após a hidroginástica deveram-se principalmente à intensidade do exercício, enquanto a PA diastólica foi influenciada pela duração do programa, particularmente as 24 semanas, e os níveis iniciais de colesterol total foram positivamente associados às alterações na PA sistólica e diastólica após o programa de hidroginástica. No geral, a hidroginástica de

alta intensidade melhora o perfil lipídico, a composição corporal e a QV física em adultos e idosos. Destacam-se também os efeitos positivos de 24 semanas de hidroginástica de alta intensidade na PA diastólica. Além disso, a hidroginástica pode aumentar a resistência muscular, independentemente da intensidade e duração utilizada. Esta tese fornece informações úteis para os instrutores de hidroginástica, sugerindo estratégias específicas para ajudar a atingir os objetivos desejados, ajustando os níveis de intensidade para atender às necessidades individuais.

Palavras-chave

Hidroginástica; intensidade; duração; aptidão física; saúde; qualidade de vida; adultos.

Abstract

Water aerobics has gained popularity, with its benefits increasingly recognized. However, there is limited information on the intensity and duration needed for optimal outcomes. This thesis explores the effects of varying intensities and durations of water aerobics on health-related variables in adults and older adults. To achieve this, the following steps were performed i) a systematic review with meta-analysis on the effects of water-based programs on the health and fitness of healthy adults and those with chronic diseases; ii) comparison of moderate versus high-intensity water aerobics (12 and 24 weeks) on muscle strength, anthropometry, lipid profile, blood pressure (BP), and quality of life (QoL); iii) analysis of the relationship between muscle strength gained after water aerobics and other factors including program intensity and duration, age, and baseline health-related variables; iv) analysis of the association between BP and lipid profile results obtained after water aerobics and factors like program intensity and duration, age, and initial health-related measurements. The findings indicated that i) few studies have assessed exercise intensity in water aerobics; ii) high-intensity water aerobics was more effective than moderate-intensity in improving lipid profile, fat mass, fat-free mass, diastolic BP, and physical QoL; iii) both durations of high-intensity water aerobics benefited diastolic BP, with greater effects after 24 weeks; iv) both programs improved muscular endurance after 12 and 24 weeks, with higher intensity related to better lower limb muscular endurance; v) psychological QoL improved after 12 weeks; vi) initial values of muscular endurance and age were related to upper limb muscular endurance and explosive strength outcomes, while initial body composition was associated with explosive strength; vii) changes in lipid profile were influenced by intensity, while diastolic BP was affected by program duration, and initial total cholesterol levels were positively associated with changes in systolic and diastolic BP. Overall, high-intensity water aerobics improves lipid profile, body composition, and physical QoL in adults and older adults. 24 weeks of this exercise also reduces diastolic BP. Water aerobics enhances muscular endurance regardless of intensity and duration. This thesis offers valuable insights for water aerobics instructors, recommending strategies to tailor intensity levels to individual needs.

Keywords

Water aerobics; intensity; duration; physical fitness; health; quality of life; adults.

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List of Acronyms

η_p^2	Partial eta squared
AC	Arm Curl
BMI	Body Mass Index
BP	Blood Pressure
BPM	Beats per minutes
CG	Control Group
CI	Confidence interval
CMJ	Countermovement Jump
CST	Chair Stand Test
CV	Coefficient of variation
ES	Effect Size
FC	Frequência cardíaca
FM	Fat mass
g	Hedges's effect size
HDL	High-density lipoprotein
HIG	High Intensity Group
HR	Heart rate
HR_{max}	Maximum heart rate
ICC	Intraclass correlation coefficient
IMC	Índice de Massa Corporal
LT	Land-based training
MG	Massa gorda
MBT	Medicine Ball Throw
MIG	Moderate Intensity Group
PA	Pressão Arterial
pRCT	Pragmatic randomized controlled trial
Pre	Assessment of variables one week before the start of the water aerobic program
Post	Assessment of variables one week after the end of the water aerobic program
QoL	Quality of Life
QV	Qualidade de vida
SD	Standard deviation
SMD	Standardized mean difference
TA	Programas de treino aquático
TC	Total Cholesterol
TG	Triglycerides / triglicéridos
VO_2	Oxygen uptake
WLT	Water-based combined with land-based training
WT	Water-based training

Chapter 1. General Introduction

Regular physical activity is key to reducing health and functional problems. However, there are certain circumstances that can limit one's ability to exercise. Individuals with low levels of physical fitness, mobility issues (e.g., due to obesity or old age), chronic medical conditions, postmenopausal women, and athletes recovering from injury may find it challenging to engage in certain physical activities (Alberton et al., 2013; Arca et al., 2013; Borreani et al., 2014; McKenzie & McLuckie, 1991; Pinto et al., 2015; Raffaelli et al., 2016; Tsourlou et al., 2006). As a result of these challenges, there has been a notable increase in the participation of these populations in aquatic exercise programs, aimed at facilitating physical activity across different age groups (Moreira et al., 2020).

Water-based exercise is considered a safe and effective option compared to land-based exercise, primarily due to the unique characteristics of the aquatic environment. These characteristics include buoyancy, the absence of hypogravity, and drag forces. The buoyancy and lack of hypogravity result in a reduced impact of body weight and compressive forces on the joints. The body's weight can be reduced by up to 90% when submerged in water, resulting in less stress on the joints and spine, and an increased range of motion compared to land. Additionally, the increased drag force in water allows for external loading during most movements, increasing energy expenditure (Borreani et al., 2015; Kantyka et al., 2015; Penaforte et al., 2015; Rica et al., 2012; Takeshima et al., 2002; Tsourlou et al., 2006). This load can be increased with faster movements or by adjusting the projected frontal area (using different body positions in the water and equipment that creates resistance to movement) (Colado et al., 2008; Colado et al., 2009a; Colado et al., 2009b; Harrison et al., 1992; Pinto et al., 2011; Raffaelli et al., 2010). Despite this known information about the specifics of the aquatic environment, there is a lack of meta-analyses that examine the effects of different aquatic exercise regimens on health and physical fitness in multiple populations. It is essential to categorize the existing research findings in the literature to assess effect size and understand the impact of each aquatic program on specific outcomes in both healthy adults and those with specific diseases (Study 1). This will allow the development of practical recommendations for health and exercise professionals.

In terms of aquatic exercise programs, water aerobics has received considerable attention from the scientific community (Antunes et al. 2015; Benelli et al., 2004) due to its distinctive characteristics. These include a wide range of movements that are responsible for working several large muscle groups simultaneously, strengthening both the concentric and eccentric movements (Green, 1989; Gusi et al., 2006). The movements are performed to counteract the effects of gravity and improve physical abilities (López et al., 2017). In addition, it is an activity with minimal risk of impact-related injuries, making it particularly popular among adults and older adults (Kantyka et al., 2015; López et al., 2017).

The exercise intensity of water aerobics varies primarily to create an aerobic workout, consisting of a warm-up phase, a more vigorous aerobic phase, and a cool-down phase (Krasevec & Grimes, 1984). Different exercises can be performed during each phase of the class, including walking, running, rocking, kicking, jumping, and scissors (Sanders, 2000). Compared to other aquatic activities, an advantage of this sport is the availability of multiple variations for each exercise, allowing for a wide variety of training routines (Barbosa et al., 2009). Additionally, each exercise can be performed with the simultaneous or sequential action of different segments of the body. For example, using only leg or arm movements, or working the lower and upper limbs simultaneously (Barbosa et al., 2009). When comparing different options, some studies have shown that working the arms and legs simultaneously results in a superior physiological response (Darby & Yaeckle, 2000; Costa et al., 2008), due to the increase in drag forces and the activation of a greater number of muscles (Barbosa et al., 2009; Yu et al., 1994). The position of the hands and fingers during movements is also important in achieving the desired effort (Barbosa et al., 2009). Performing a particular movement with minimal distance between the fingers results in greater drag forces than performing the same movement with fingers close together or wide apart (Marinho et al., 2010). Furthermore, certain aquatic equipment, such as flotation vests, ankle cuffs, and dumbbells, can elicit different responses during classes (Barbosa et al., 2009). Flotation vests and ankle cuffs assist with buoyancy, allowing a person to maintain an upright position in deep water, while dumbbells increase resistance in the water (Barbosa et al., 2009; Costa et al., 2008).

The American College of Sports Medicine recommends that aerobic exercise be performed at an intensity of 64% to 94% of the maximum heart rate (HR_{max}), 40% to 85% of the HR reserve, and a perceived exertion rating of 12 to 16 to produce benefits in several health-related variables (Bayles et al., 2023). It is also known that a typical water aerobics class performed at chest level depth elicits mean HR responses of 66% to 78% of maximum (D'Acquisto et al., 2001; Campbell et al., 2003), in adults and older adults. These findings are consistent with the cardiovascular responses recommended by the ACSM guidelines (Nikolai et al., 2009). In analyzing the performance of aquatic exercises at different depths, it has been noted that the physiological demands are greater at shallower depths. Evidence suggests that greater immersion significantly reduces HR (Barbosa et al., 2007; Benelli et al., 2004). This phenomenon may be due to buoyancy and hydrostatic pressure, which promote a larger systolic volume as a result of more efficient filling of the heart during diastole (Holmér, 1974), and to the greater volume of blood distributed in the trunk (Sheldahl et al., 1987). The shallower the depth (e.g., hip vs. chest), the greater the subjective perception of effort (Barbosa et al., 2007). This is likely due to reduced buoyancy, which increases ground reaction forces (Nakazawa et al., 1994), or differences in active muscles at different depths (Fujisawa et al., 1998; Poyhonen et al., 1999; Poyhonen et al., 2001). Oxygen uptake (VO_2) also decreases at greater depths (Barbosa et al., 2007) due to the increased hydrostatic pressure, which reduces cardiovascular training. Additionally, the propulsive force is responsible for reducing the work of the antigravity and postural muscles (Butts et al., 1991).

Several studies have examined the acute and chronic effects of water aerobics on the health and physical fitness of diverse populations. Regardless of the specific outcomes associated with water aerobic exercise, evidence highlights its influence on muscular strength, body composition, and cardiorespiratory fitness (Andrade et al., 2020; Alves et al., 2004; Farinha et al., 2021; Jasinski et al., 2015; Moreira et al., 2017; Neiva et al., 2018; Novaes et al., 2014; López et al., 2017; Takeshima et al., 2002; Tsourlou et al., 2006; Waters & Hale, 2007). Although current research is limited, there is increased interest in the effects of water aerobics on blood pressure (BP) and lipid profiles (Arca et al., 2014; Kantyka et al., 2015; Moura et al., 2020; Sobczak et al., 2023). Despite this, the well-being of individuals engaged in this activity has not been sufficiently emphasized (Garrido et al., 2016). Some studies have focused on the effects of medium- and long-term training programs, while others have investigated the acute effects of this exercise modality, often examining the outcomes of only one or two training sessions (Cunha et al., 2016; Kruel et al., 2021). Despite these different approaches, the current body of evidence is insufficient to determine the optimal duration of training necessary to achieve meaningful improvements in health and physical fitness. Further research is needed to determine the most effective duration of exercise required to maximize these benefits.

Additionally, exercise intensity is a critical factor in the prescription of any physical activity (Nikolai et al., 2009). Participating in a water aerobics class at an intensity below the minimum required may prevent the achievement of the desired benefits. Conversely, exercising at excessively high intensities can lead to overtraining, which can negatively affect outcomes (Franklin et al., 2007; Nikolai et al., 2009). Thus, improvements in various health-related variables across different age groups and populations depend on the accurate prescription of exercises and the achievement of appropriate exercise intensities to facilitate adaptation. However, several studies fail to monitor the intensity used (Alves et al., 2004; Garrido et al., 2016; Green et al., 1989; Moura et al., 2020; Novaes et al., 2014). Most of the research that provides this information focuses on exercise performed at low to moderate intensities, with only a limited number of studies investigating performance at high intensities (Andrade et al., 2020; Moreira et al., 2017; Tsourlou et al., 2006).

Based on this information, several studies have analyzed various health-related variables in water aerobics programs of varying durations and evaluated the effects of exercise intensity. However, there is insufficient data to determine the optimal duration and intensity of these exercises to achieve desired outcomes in adults and older adults. Furthermore, previous research has not conducted comparative analyses of different exercise intensities within this modality. Therefore, it is important for future studies to examine and compare the effects of different durations and intensities levels of water aerobics. Such studies should particularly emphasize key health-related variables, including physical fitness levels, cardiovascular health indicators, and overall well-being (Studies 2 and 3). This information may provide valuable insights into how to tailor water aerobics to effectively address the health needs of different age groups, with a particular focus on adults and older adults. Thus, it is important to determine whether the results of these water aerobics programs are due to these specific factors (program intensity and duration), or whether they are also influenced by the age of the participants and their baseline health-related variables before starting the programs. This analysis will help to understand the relationship between the program characteristics and individual participant characteristics, thereby providing deeper insights into the effectiveness of water aerobics (Studies 4 and 5).

Given the above, the main purpose of this thesis was to analyze the effects of different intensities and durations of water aerobics on health-related variables in adults and older adults. Specifically, the aim was to evaluate and compare the effectiveness of each water aerobics program on muscular strength, body composition, BP, lipid profile, and quality of life (QoL). To achieve this purpose, this thesis was structured according to the following sequence:

i) Chapter 2 presents a systematic review with meta-analysis aimed at synthesizing and analyzing data on the effects of water-based training programs on the health status and physical fitness of healthy adults and adults with chronic diseases (Study 1).

ii) Chapter 3 groups the following experimental studies developed to reach the main body of the thesis:

- Study 2 determines the effects of a 12-week regimen of moderate versus high-intensity water aerobic exercise on muscle strength, body composition, lipid profile, BP, and QoL in adults and older adults.

- Study 3 compares the effects of a 24-week program of moderate and high-intensity water aerobics on muscle strength, anthropometric, lipid profile, BP, and QoL in adults and older adults.

- Study 4 analyzes the relationship between muscle strength achieved through water aerobics programs and several factors, including program intensity and duration, age of participants, and baseline measures of muscle strength, body composition, and QoL.

- Study 5 examines the relationship between BP and lipid profile outcomes of water aerobics programs and factors such as program intensity and duration, age of participants, and their baseline BP, lipid profile, anthropometric, and QoL levels.

iii) Chapter 4 provides a general discussion with a broad overview of the findings from the studies conducted. iv) Chapter 5 outlines the main conclusions drawn from the thesis. v) Chapter 6 provides recommendations for future research related to the topic addressed. vi) Chapter 7 lists the bibliographic references that support this thesis.

Chapter 2. Literature Review

Study 1. Benefits of aquatic exercise in adults with and without chronic disease - A systematic review with meta-analysis

Abstract

Aquatic exercise is being increasingly recommended for healthy individuals as well as people with some special health conditions. A systematic review with meta-analysis was performed to synthesize and analyse data on the effects of water-based training (WT) programs on health status and physical fitness of healthy adults and adults with diseases to develop useful recommendations for health and sports professionals. We searched three databases (PubMed, Web of Science, and Scopus) up to June 2021 for randomized and non-randomized trials that examined WT in adults. A total of 62 studies were included, of which 26 involved only healthy individuals and 36 focused on adults with chronic diseases. In the healthy group, the effects of WT on strength, balance, and cardiorespiratory fitness were beneficial, indicating the usefulness of performing WT for at least 12 weeks (2-3x/week, 46-65 min/session). Among adults with diseases, improvements were observed in patients with fibromyalgia (in balance and cardiorespiratory fitness), bone diseases (pain, balance, flexibility and strength), coronary artery disease (strength and anthropometry), hypertension (quality of life), stroke (quality of life), diabetes (balance and quality of life), multiple sclerosis (quality of life and balance), and Parkinson's disease (pain, gait, cardiorespiratory fitness and quality of life). Research is required to determine the effects of WT on patients with heart disease, especially on coronary artery disease. In adults with chronic disease, benefits in physical fitness and/or other health-related measures were mainly observed after 8-16 weeks of training. WT is an effective physical activity when the intention is to enhance health and physical fitness in healthy adults and adults with chronic diseases.

Introduction

The popularity of aquatic exercise has increased exponentially in the last two decades (Martinez et al., 2015; Raffaelli et al., 2016). This increase is likely due to the properties of water, namely, buoyancy, drag forces, and the lack of hypo gravity (Neiva et al., 2018; Poyhonen et al., 2002). Buoyancy and lack of hypo gravity are responsible for reducing the effect of body weight, compression forces, and joints, while drag forces provide resistance during movement (Kumar et al., 2015; Tsourlou et al., 2006). Thus, aquatic exercise requires much more intense effort but leads to less perceived effort than similar nonwatery activities (López et al., 2017). Therefore, aquatic exercise may be useful for performing physical exercise and improving health and physical fitness indicators.

In addition to knowledge about the characteristics of the water, it is important to identify and describe the existing knowledge regarding the effects of water-based training (WT) on health and physical fitness indicators. Some studies have found that WT has positive effects on several health and physical fitness parameters (Bocalini et al., 2008; Kanitz et al., 2015), while others have shown WT to be less effective (Bocalini et al., 2008; Penaforte et al., 2015; Taunton et al., 1996), indicating that there are divergent results and uncertainty regarding the effects of WT on health and physical fitness indicators. These divergent results were possibly due to the use of different methodologies, specifically regarding the duration of the training program and the intensity used (Lambert et al., 2014), and the inclusion and comparison of populations with different characteristics, such as people of different ages.

In general, WT has been recommended for people with special health conditions (e.g., older adults, obese people, postmenopausal women, subjects with coronary artery disease, and athletes treating injuries) (Raffaelli et al., 2016) as well as for healthy individuals. Due to the uncertainty regarding the effects of WT, it is necessary to determine the importance of practicing these activities among people with and without chronic diseases and to identify the main effects of WT based on specific diseases. To the best of our knowledge, no detailed systematic review has exhaustively explored the literature to determine the effects of WT on physical fitness and health-related outcomes in healthy and diseased adult populations. Therefore, the primary purpose of this systematic review was to synthesize and analyse research findings about the effects of WT on health status and physical fitness in this cohort of subjects. We analyzed data from healthy adults as well as adults with diseases to develop useful recommendations for health and sports professionals.

Methods

Literature Search

The current systematic review with meta-analysis was registered in PROSPERO (number: CRD42020147331) and was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) and the Cochrane Handbook (Higgins & Green, 2011). Three databases (Web of Science, PubMed, and Scopus) were searched for randomized and nonrandomized controlled trials involving WT in healthy adults and those with some chronic diseases up to 30 June 2021. A comprehensive combination of search terms was used, including [(aquatic exercise OR aquatic activity OR in-water exercise OR water-based exercise OR aquatic training OR water-based training OR in-water training) AND (physical fitness OR health-related) AND (healthy adults OR diseased adults OR healthy elderly or diseased elderly)].

Study Selection and Data extraction

The inclusion criteria for this study were as follows: (1) randomized trials (including nonrandomized trials and randomized controlled trials); (2) adults aged ≥ 18 years; (3) healthy participants or participants with any chronic disease; (4) comparison group (WT vs. other training programs (e.g., WT with different intensity, frequency, or session duration; or land-based training (LT); or water-based combined with land-based training (WLT); or control group (CG)); and (5) without a comparison group. Any article that was not a peer-reviewed manuscript was excluded, as were studies that did not have full methods, results (pre and post and/or mean and SD data), and conclusion sections. Studies were restricted to those written in English. Qualitative reviews, systematic reviews, meta-analysis, theses, dissertations, and conference abstracts were also excluded. The outcomes used in the study had to include at least one physical fitness variable or one health-related variable and/or some specific variables related to disease outcomes. Studies were excluded if i) participants were pregnant women or adults with any type of cancer or ii) swimming was considered the training intervention. A minimum of two studies focusing on a specific disease were required to be included in the analysis, thus allowing outcomes, conclusions, and practical recommendations to be summarized. Two researchers independently extracted information from the included full-text publications, and any discrepancies were resolved by discussion until consensus was reached. The following details were extracted: age, sex, intervention period, main primary outcomes assessed, and characteristics of exercise programs (i.e., the type of exercise, session duration, frequency, and chronic diseases).

Risk of Bias

Two reviewers independently assessed the methodological quality of the studies included in the systematic review using the "risk of bias" assessment tool recommended by the Cochrane Collaboration (Higgins et al., 2011). The authors resolved disagreements by consensus, and a third author was consulted to resolve disagreements if necessary. The risk of bias of each randomized trial was assessed using the following domains: random sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting, and other bias. Each domain was judged as “low risk”, “high risk”, or “unclear risk”. If the judgment was unclear due to lack of information, insufficient detail, or uncertainty concerning the potential for bias, an “unclear risk” was given. Additionally, the risk of bias of each nonrandomized trial was evaluated using the ROBINS-I (Sterne et al., 2016) method, scoring each study with the following domains: confounding, selection of participants, classification of interventions, deviation from intended interventions, missing data, measurement of outcomes, and selection of the reported results. These domains were classified as “low”, “moderate”, “serious”, “critical” or “no information”. Review Manager Software (version 5.4; The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) was used to create risk-of-bias graphs in randomized studies, while for non-randomized studies we used the robvis tool.

Data analysis

The meta-analysis to determine the effect of the different WT programs in healthy adults and adults with chronic diseases was conducted using Review Manager software (version 5.4; The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). The WT programs effects on healthy adults were analyzed regarding anthropometrics, balance, blood pressure (BP), cardiorespiratory fitness, flexibility, quality of life (QoL), and strength (subgroups). Depending on the disease (i.e., musculoskeletal diseases, heart diseases, diabetes mellitus, multiple sclerosis, and Parkinson's disease), anthropometrics, balance, cardiorespiratory fitness, flexibility, pain, QoL, strength, lipid profile, and gait variables were analyzed as subgroups. As there was no CG in most of the studies, the means and standard deviation from pre-and post-intervention were used to determine the intervention effect. This intervention effect was calculated using the standardized mean difference (SMD) for each study and 95% confidence intervals (95% CI). In each subgroup, in healthy adults or each chronic disease, the overall WT effects were calculated (Z-test) and the weighted mean differences and 95% CI were computed for continuous variables, using a Mantel-Haenszel fixed-effect method in cases of low statistical inconsistency ($I^2 \leq 50\%$) and using a DerSimonian and Laird random-effect method in cases of moderate or high statistical inconsistency ($I^2 > 50\%$) (Higgins et al., 2003). Statistical heterogeneity was measured by using the Cochrane chi-squared test and the I^2 (Higgins et al., 2011). Results were considered statistically significant at $p < 0.05$ and the magnitude of the intervention effect was classified as small (d=0.20), medium (d=0.50), and large (d=0.80) (Cohen, 1988; Cohen, 2013). The negative values of the SMD favour the benefits of the WT, while the positive values favour the harmful effects of WT. Additionally, in the case of outcomes whose number of articles is insufficient to perform a meta-analysis (for example, diabetes mellitus and multiple sclerosis), the results will be discussed as a systematic review, not using the SMD.

Results

The initial search included 795 articles; after excluding duplicate studies, 713 potentially relevant articles remained. Then, 613 studies were excluded after screening the titles and abstracts, and other 38 studies were excluded for other reasons. Of these, 62 full-text articles were assessed for eligibility, of which 26 articles were included in the analysis of the effects of WT on healthy adults, while 36 studies were included in the analysis of the effects of WT on adults with chronic disease. Among these, 54 studies were included for quantitative analysis (meta-analysis), 26 of which refer to healthy adults and 28 to adults with chronic diseases. A detailed flow chart describing the process of selecting the relevant studies is shown in Figure 1.

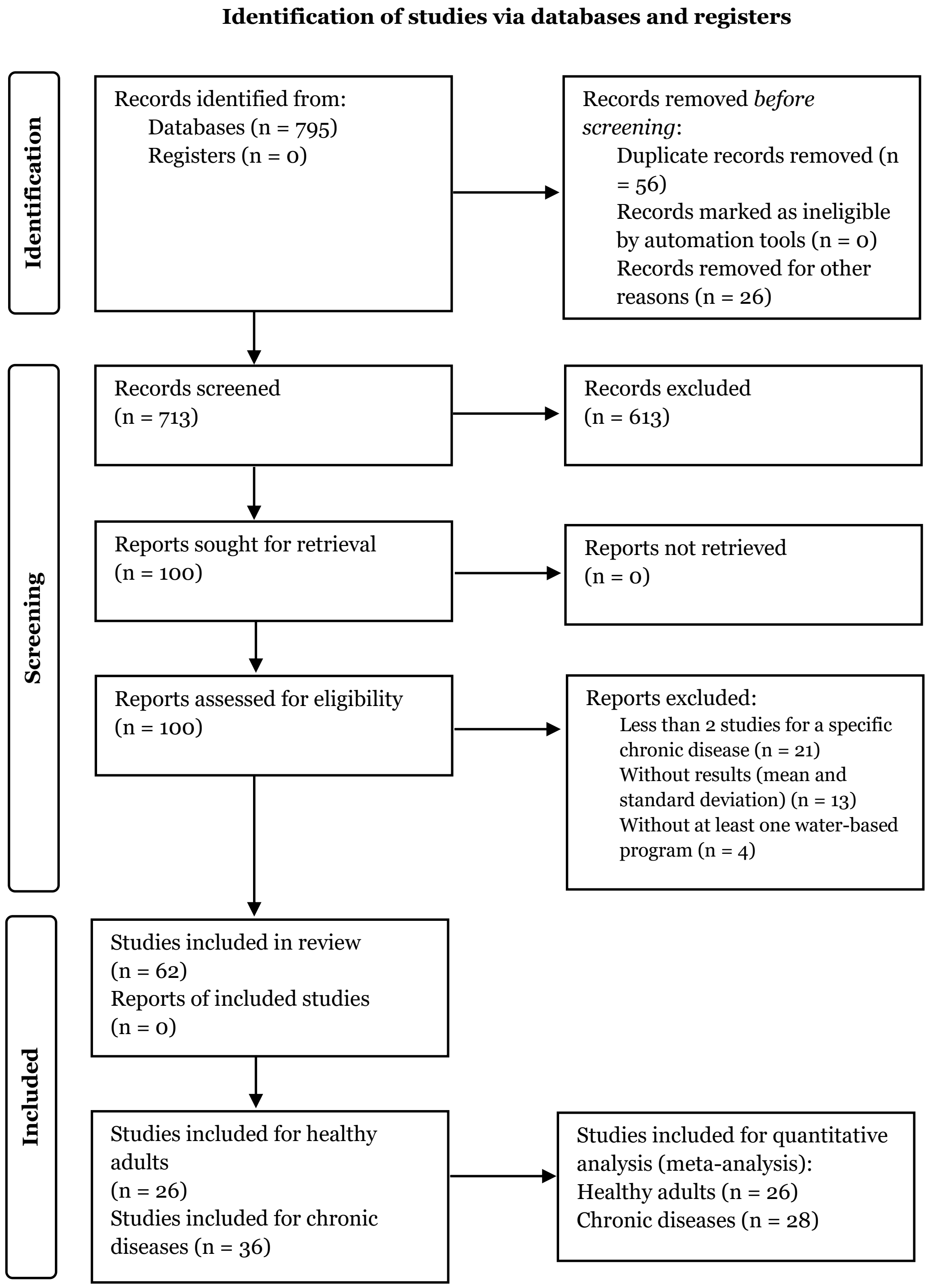


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart for study identification.

The extracted data were synthesized based on the sample of the study, specifically healthy adults (Table 1), and adults with chronic diseases, namely musculoskeletal diseases, heart diseases, diabetes mellitus, multiple sclerosis, and Parkinson's disease (Table 2). The main outcomes were health-related (i.e., lipid profile, BP, QoL, gait, fatigue, and perception of pain) and physical fitness outcomes (i.e., strength, balance, cardiorespiratory fitness, anthropometrics, and flexibility).

Healthy adults

Of the 26 exercise trials included, 9 studies compared one type of WT with another WT (of which 3 studies also included a CG), 7 studies compared WT with LT (of which 2 studies also included a CG), and 10 other articles compared a WT to a CG. It should also be noted that the minimum duration of the training programs was 4 weeks, and the maximum duration was 28 weeks; approximately 77% of studies lasted between 8 and 12 weeks.

Regarding WT, most of the results revealed positive effects (Figure 2), obtaining greater effects especially in strength, cardiorespiratory fitness, and balance. Specifically, in these variables we found that WT programs had considerable benefits in strength [medium (López et al., 2017) and large (Poyhonen et al., 2002; Reichert et al., 2016; Reichert et al., 2018; Robinson et al., 2004; Sanders et al., 2013; Seyedjafari et al., 2017; Tsourlou et al., 2006; Vale et al., 2020)], cardiorespiratory fitness [intermediate (Reichert et al., 2016; Sanders et al., 2013) and large (Lambert et al., 2014; Reichert et al., 2018)], and balance [intermediate (Reichert et al., 2016) and large (López et al., 2017; Reichert et al., 2016; Sanders et al., 2013; Seyedjafari et al., 2017; Tsourlou et al., 2006; Vale et al., 2020)]. The overall effect showed that WT programs are responsible for positive effects on health status and physical fitness in healthy adults (medium effect).

Table 1. Effects of water-based activities on healthy population.

Author	Subjects	Intervention Period	Design	Intervention	Parameters Assessed
Oliveira et al. (2014)	74 F (69 y)	12 weeks [2/week]	RCT	WT: 40-45′ MW + 15-20′ Str LT_1: 40-45′ mini-trampoline + 15-20′ Str LT_2: 40-45′ floor gymnastics + 15-20′ Str	Balance
López et al. (2017)	26 F (67.45 y)	12 weeks [5/week]	RCT	WT: 10′ W + 30′ MW + 10′ Str CG: without intervention	Balance, Cardiorespiratory Fitness, Flexibility, Strength
Martinez et al. (2015)	26 F (67.45 y)	12 weeks [5/week]	RCT	WT: 10′ W + 30′ MW + 10′ Str CG: without intervention	Quality of Life
Poyhonen et al. (2002)	24 F (34.2 y)	10 weeks [2-3/week]	RCT	WT: 6-8′ W + 30-45′ RT + 5′ Str CG: without intervention	Strength
Tsourlou et al. (2006)	22 F (68.85 y)	24 weeks [3/week]	RCT	WT: 10′ W + 25′ AT + 20′ RTRE + 5′ Str CG: without intervention	Anthropometrics, Balance, Flexibility, Strength
Vale et al. (2020)	52 F (67.3 y)	16 weeks [2/week]	RCT	WT: 60′ intervention GC: without intervention	Balance, Flexibility, Strength
Graef et al. (2010)	27 F (66.69 y)	12 weeks [2/week]	RCT	WT_1: 50’ [W + ATRE + Str] WT_2: 50’ [W + AT + Str] CG: without intervention	Strength
Moreira et al. (2017)	90 F (65.3 y)	12 weeks [3/week]	RCT	WT_1: 5′ W + 35′ MW lower limbs + 5′ Str WT_2: 5′ W + 35′ MW + 5′ Str CG: without intervention	Balance, Cardiorespiratory Fitness, Flexibility, Strength
Jurado-Lavanant et al. (2015)	65 M (21.2 y)	10 weeks [2/week]	RCT	WT: PlyoT LT: PlyoT CG: without intervention	Strength

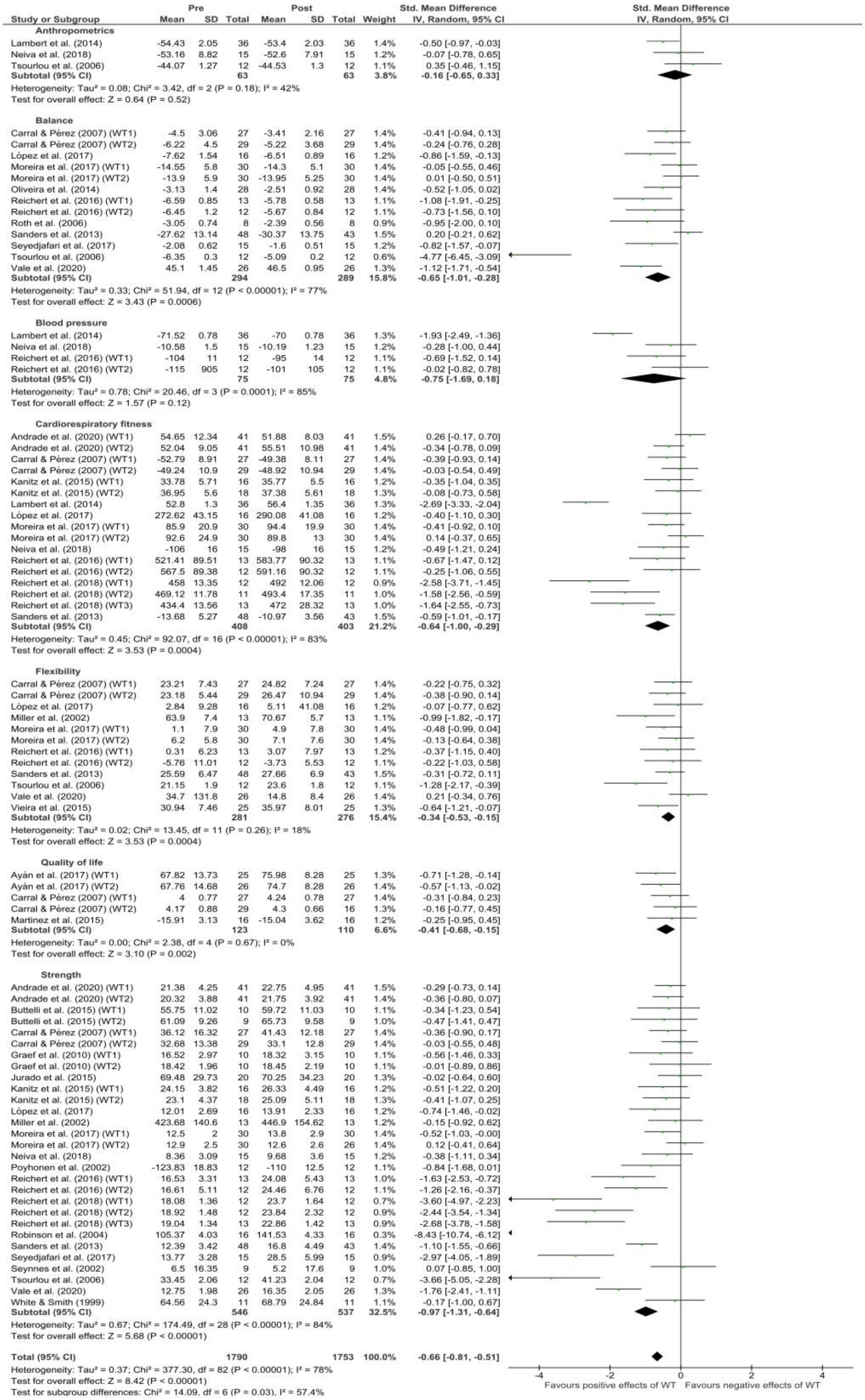
Table 1. Continued.

Author	Subjects	Intervention Period	Design	Intervention	Parameters Assessed
Miller et al. (2002)	24 F + 19 M (22.16 y)	8 weeks [2/week]	RCT	WT: PlyoT LT: PlyoT CG: without intervention	Flexibility, Strength
Roth et al. (2006)	17 F + 7 M (21.81 y)	4 weeks [3/week]	RCT	WT: 30′ intervention LT: 30′ intervention CG: without intervention	Balance
Reichert et al. (2018)	36 F (67.53 y)	12 weeks [2/week]	RCT	WT_1: 7′ W + 13′ RT + 10′ Str WT_2: 7′ W + 28′ RT + 10′ Str WT_3: 7′ W + 9′ RT + 10′ Str CG: dance and gymnastics classes	Cardiorespiratory Fitness, Strength
Ayán et al. (2017)	51 F (46.5 y)	24 weeks [2/week]	Non-RCT	WT_1: 12 weeks SCF + 12 weeks FE WT_2: 12 weeks FE + 12 weeks SCF	Quality of Life
Seynnes et al. (2002)	14 F + 4 M (72.7 y)	11 weeks [2/week]	Non-RCT	WT: 45′ intervention LT: 60′ intervention	Strength
Neiva et al. (2018)	19 F + 4 M (58.9 y)	12 weeks [2/week]	Non-RCT	WT: 8′ W + 27′ AT + 10′ SE + 5′ Str CG: without intervention	Anthropometrics, Blood Pressure, Cardiorespiratory Fitness, Strength
Sanders et al. (2013)	66 F (73.2 y)	16 weeks [3/week]	Non-RCT	WT: 10′ W + 35′ SE + 10′ Str CG: without intervention	Balance, Cardiorespiratory Fitness, Flexibility, Strength
Seyedjafari et al. (2017)	30 M (66 y)	8 weeks [3/week]	Non-RCT	WT: 10′ W + 45′ MW + 5′ Str CG: without intervention	Balance, Strength
Vieira et al. (2015)	46 F (67.95 y)	12 weeks [2/week]	Non-RCT	WT: 50′ intervention CG: 45′ flexibility intervention	Flexibility

Table 1. Continued.

Author	Subjects	Intervention Period	Design	Intervention	Parameters Assessed
White & Smith (1999)	14 F + 4 M (29.15 y)	8 weeks [3/week]	Non-RCT	WT: 5′ W + 40′ MW + 5′ Str CG: without intervention	Strength
Buttelli et al. (2015)	21 M (21 y)	10 weeks [2/week]	RCLT	WT$_1$: 5′ W + 25′ RT + 8′ Str WT$_2$: 5′ W + 50′ RT + 8′ Str	Strength
Carral & Pérez (2007)	62 F (68.4 y)	20 weeks [5/week]	RCLT	WT$_1$: 10-20′ W + 15-30′ ST + 5-10′ Str WT$_2$: 10-20′ W + 15-30′ CalT + 5-10′ Str	Balance, Cardiorespiratory Fitness, Flexibility, Strength, Quality of Life
Kanitz et al. (2015)	34 M (65 y)	12 weeks [3/week]	RCLT	WT$_1$: 30′ ET WT$_2$: 30′ CT	Cardiorespiratory Fitness, Strength
Reichert et al. (2016)	18 F + 18 M (67.9 y)	28 weeks [2/week]	RCLT	WT$_1$: 5′ W + 30-36′ ConT + 4-10′ Str WT$_2$: 5′ W + 30-36′ IT + 4-10′ Str	Balance, Blood Pressure, Cardiorespiratory Fitness, Flexibility; Strength
Andrade et al. (2020)	41 F (64.35 y)	12 weeks [2/weeks]	RCLT	WT$_1$: 4’ W + 36’ ConT + 4’ Str WT$_2$: 4’ W + 36’ IT + 4’ Str	Cardiorespiratory Fitness, Strength
Lambert et al. (2014)	30 F + 30 M (41.5 y)	12 weeks [3/week]	RCLT	WT: ND LT: ND	Anthropometrics, Blood Pressure, Cardiorespiratory Fitness
Robinson et al. (2004)	32 F (20.2 y)	8 weeks [3/week]	RCLT	WT: 10′ W + 50′ PlyoT + 5′ Str LT: 10′ W + 50′ PlyoT + 5′ Str	Strength

AT Aerobic Training, *ATRE* Aerobic Training with Resistive Equipment, *CalT* Calisthenic Training, *CG* Control Group, *CT* Concurrent Training, *ConT* Continuous Training, *ET* Endurance Training, *F* Female, *FE* Fitness Exercises, *IT* Interval Training, *LT* Land-based Training, *M* Male, *MW* Main Workout, *ND* Not Defined, *Non-RCT* Non-Randomized Controlled Trial, *PlyoT* Plyometric Training, *RCT* Randomized Controlled Trial, *RCLT* Randomized clinical trial, *RT* Resistance Training, *RTRE* Resistance Training with Resistive Equipment, *Str* Stretching, *SE* Specific Exercitations, *SCF* Stimulation of Cognitive Function, *W* Warm-up, *WT* Water-based Training, *y* years old



Study or Subgroup	Pre Mean	Pre SD	Pre Total	Post Mean	Post SD	Post Total	Weight	Std. Mean Difference IV, Random, 95% CI
Anthropometrics								
Lambert et al. (2014)	-54.43	2.05	36	-53.4	2.03	36	1.4%	-0.50 [-0.97, -0.03]
Neiva et al. (2018)	-53.16	8.82	15	-52.6	7.91	15	1.2%	-0.07 [-0.78, 0.65]
Tsourlou et al. (2006)	-44.07	1.27	12	-44.53	1.3	12	1.1%	0.35 [-0.46, 1.15]
Subtotal (95% CI)			**63**			**63**	**3.8%**	**-0.16 [-0.65, 0.33]**
Heterogeneity: Tau² = 0.08; Chi² = 3.42, df = 2 (P = 0.18); I² = 42%								
Test for overall effect: Z = 0.64 (P = 0.52)								
Balance								
Carral & Pérez (2007) (WT1)	-4.5	3.06	27	-3.41	2.16	27	1.4%	-0.41 [-0.94, 0.13]
Carral & Pérez (2007) (WT2)	-6.22	4.5	29	-5.22	3.68	29	1.4%	-0.24 [-0.76, 0.28]
López et al. (2017)	-7.62	1.54	16	-6.51	0.89	16	1.2%	-0.86 [-1.59, -0.13]
Moreira et al. (2017) (WT1)	-14.55	5.8	30	-14.3	5.1	30	1.4%	-0.05 [-0.55, 0.46]
Moreira et al. (2017) (WT2)	-13.9	5.9	30	-13.95	5.25	30	1.4%	0.01 [-0.50, 0.51]
Oliveira et al. (2014)	-3.13	1.4	28	-2.51	0.92	28	1.4%	-0.52 [-1.05, 0.02]
Reichert et al. (2016) (WT1)	-6.59	0.85	13	-5.78	0.58	13	1.1%	-1.08 [-1.91, -0.25]
Reichert et al. (2016) (WT2)	-6.45	1.2	12	-5.67	0.84	12	1.1%	-0.73 [-1.56, 0.10]
Roth et al. (2006)	-3.05	0.74	8	-2.39	0.56	8	0.9%	-0.95 [-2.00, 0.10]
Sanders et al. (2013)	-27.62	13.14	48	-30.37	13.75	43	1.5%	0.20 [-0.21, 0.62]
Seyedjafari et al. (2017)	-2.08	0.62	15	-1.6	0.51	15	1.2%	-0.82 [-1.57, -0.07]
Tsourlou et al. (2006)	-6.35	0.3	12	-5.09	0.2	12	0.6%	-4.77 [-6.45, -3.09]
Vale et al. (2020)	45.1	1.45	26	46.5	0.95	26	1.3%	-1.12 [-1.71, -0.54]
Subtotal (95% CI)			**294**			**289**	**15.8%**	**-0.65 [-1.01, -0.28]**
Heterogeneity: Tau² = 0.33; Chi² = 51.94, df = 12 (P < 0.00001); I² = 77%								
Test for overall effect: Z = 3.43 (P = 0.0006)								
Blood pressure								
Lambert et al. (2014)	-71.52	0.78	36	-70	0.78	36	1.3%	-1.93 [-2.49, -1.36]
Neiva et al. (2018)	-10.58	1.5	15	-10.19	1.23	15	1.2%	-0.28 [-1.00, 0.44]
Reichert et al. (2016) (WT1)	-104	11	12	-95	14	12	1.1%	-0.69 [-1.52, 0.14]
Reichert et al. (2016) (WT2)	-115	905	12	-101	105	12	1.1%	-0.02 [-0.82, 0.78]
Subtotal (95% CI)			**75**			**75**	**4.8%**	**-0.75 [-1.69, 0.18]**
Heterogeneity: Tau² = 0.78; Chi² = 20.46, df = 3 (P = 0.0001); I² = 85%								
Test for overall effect: Z = 1.57 (P = 0.12)								
Cardiorespiratory fitness								
Andrade et al. (2020) (WT1)	54.65	12.34	41	51.88	8.03	41	1.5%	0.26 [-0.17, 0.70]
Andrade et al. (2020) (WT2)	52.04	9.05	41	55.51	10.98	41	1.4%	-0.34 [-0.78, 0.09]
Carral & Pérez (2007) (WT1)	-52.79	8.91	27	-49.38	8.11	27	1.4%	-0.39 [-0.93, 0.14]
Carral & Pérez (2007) (WT2)	-49.24	10.9	29	-48.92	10.94	29	1.4%	-0.03 [-0.54, 0.49]
Kanitz et al. (2015) (WT1)	33.78	5.71	16	35.77	5.5	16	1.2%	-0.35 [-1.04, 0.35]
Kanitz et al. (2015) (WT2)	36.95	5.6	18	37.38	5.61	18	1.3%	-0.08 [-0.73, 0.58]
Lambert et al. (2014)	52.8	1.3	36	56.4	1.35	36	1.3%	-2.69 [-3.33, -2.04]
López et al. (2017)	272.62	43.15	16	290.08	41.08	16	1.2%	-0.40 [-1.10, 0.30]
Moreira et al. (2017) (WT1)	85.9	20.9	30	94.4	19.9	30	1.4%	-0.41 [-0.92, 0.10]
Moreira et al. (2017) (WT2)	92.6	24.9	30	89.8	13	30	1.4%	0.14 [-0.37, 0.65]
Neiva et al. (2018)	-106	16	15	-98	16	15	1.2%	-0.49 [-1.21, 0.24]
Reichert et al. (2016) (WT1)	521.41	89.51	13	583.77	90.32	13	1.1%	-0.67 [-1.47, 0.12]
Reichert et al. (2016) (WT2)	567.5	89.38	12	591.16	90.32	12	1.1%	-0.25 [-1.06, 0.55]
Reichert et al. (2018) (WT1)	458	13.35	12	492	12.06	12	0.9%	-2.58 [-3.71, -1.45]
Reichert et al. (2018) (WT2)	469.12	11.78	11	493.4	17.35	11	1.0%	-1.58 [-2.56, -0.59]
Reichert et al. (2018) (WT3)	434.4	13.56	13	472	28.32	13	1.0%	-1.64 [-2.55, -0.73]
Sanders et al. (2013)	-13.68	5.27	48	-10.97	3.56	43	1.5%	-0.59 [-1.01, -0.17]
Subtotal (95% CI)			**408**			**403**	**21.2%**	**-0.64 [-1.00, -0.29]**
Heterogeneity: Tau² = 0.45; Chi² = 92.07, df = 16 (P < 0.00001); I² = 83%								
Test for overall effect: Z = 3.53 (P = 0.0004)								
Flexibility								
Carral & Pérez (2007) (WT1)	23.21	7.43	27	24.82	7.24	27	1.4%	-0.22 [-0.75, 0.32]
Carral & Pérez (2007) (WT2)	23.18	5.44	29	26.47	10.94	29	1.4%	-0.38 [-0.90, 0.14]
López et al. (2017)	2.84	9.28	16	5.11	41.08	16	1.2%	-0.07 [-0.77, 0.62]
Miller et al. (2002)	63.9	7.4	13	70.67	5.7	13	1.1%	-0.99 [-1.82, -0.17]
Moreira et al. (2017) (WT1)	1.1	7.9	30	4.9	7.8	30	1.4%	-0.48 [-0.99, 0.04]
Moreira et al. (2017) (WT2)	6.2	5.8	30	7.1	7.6	30	1.4%	-0.13 [-0.64, 0.38]
Reichert et al. (2016) (WT1)	0.31	6.23	13	3.07	7.97	13	1.2%	-0.37 [-1.15, 0.40]
Reichert et al. (2016) (WT2)	-5.76	11.01	12	-3.73	5.53	12	1.1%	-0.22 [-1.03, 0.58]
Sanders et al. (2013)	25.59	6.47	48	27.66	6.9	43	1.5%	-0.31 [-0.72, 0.11]
Tsourlou et al. (2006)	21.15	1.9	12	23.6	1.8	12	1.1%	-1.28 [-2.17, -0.39]
Vale et al. (2020)	34.7	131.8	26	14.8	8.4	26	1.4%	0.21 [-0.34, 0.76]
Vieira et al. (2015)	30.94	7.46	25	35.97	8.01	25	1.3%	-0.64 [-1.21, -0.07]
Subtotal (95% CI)			**281**			**276**	**15.4%**	**-0.34 [-0.53, -0.15]**
Heterogeneity: Tau² = 0.02; Chi² = 13.45, df = 11 (P = 0.26); I² = 18%								
Test for overall effect: Z = 3.53 (P = 0.0004)								
Quality of life								
Ayán et al. (2017) (WT1)	67.82	13.73	25	75.98	8.28	25	1.3%	-0.71 [-1.28, -0.14]
Ayán et al. (2017) (WT2)	67.76	14.68	26	74.7	8.28	26	1.4%	-0.57 [-1.13, -0.02]
Carral & Pérez (2007) (WT1)	4	0.77	27	4.24	0.78	27	1.4%	-0.31 [-0.84, 0.23]
Carral & Pérez (2007) (WT2)	4.17	0.88	29	4.3	0.66	16	1.3%	-0.16 [-0.77, 0.45]
Martinez et al. (2015)	-15.91	3.13	16	-15.04	3.62	16	1.2%	-0.25 [-0.95, 0.45]
Subtotal (95% CI)			**123**			**110**	**6.6%**	**-0.41 [-0.68, -0.15]**
Heterogeneity: Tau² = 0.00; Chi² = 2.38, df = 4 (P = 0.67); I² = 0%								
Test for overall effect: Z = 3.10 (P = 0.002)								
Strength								
Andrade et al. (2020) (WT1)	21.38	4.25	41	22.75	4.95	41	1.5%	-0.29 [-0.73, 0.14]
Andrade et al. (2020) (WT2)	20.32	3.88	41	21.75	3.92	41	1.4%	-0.36 [-0.80, 0.07]
Buttelli et al. (2015) (WT1)	55.75	11.02	10	59.72	11.03	10	1.1%	-0.34 [-1.23, 0.54]
Buttelli et al. (2015) (WT2)	61.09	9.26	9	65.73	9.58	9	1.0%	-0.47 [-1.41, 0.47]
Carral & Pérez (2007) (WT1)	36.12	16.32	27	41.43	12.18	27	1.4%	-0.36 [-0.90, 0.17]
Carral & Pérez (2007) (WT2)	32.68	13.38	29	33.1	12.8	29	1.4%	-0.03 [-0.55, 0.48]
Graef et al. (2010) (WT1)	16.52	2.97	10	18.32	3.15	10	1.1%	-0.56 [-1.46, 0.33]
Graef et al. (2010) (WT2)	18.42	1.96	10	18.45	2.19	10	1.1%	-0.01 [-0.89, 0.86]
Jurado et al. (2015)	69.48	29.73	20	70.25	34.23	20	1.3%	-0.02 [-0.64, 0.60]
Kanitz et al. (2015) (WT1)	24.15	3.82	16	26.33	4.49	16	1.2%	-0.51 [-1.22, 0.20]
Kanitz et al. (2015) (WT2)	23.1	4.37	18	25.09	5.11	18	1.3%	-0.41 [-1.07, 0.25]
López et al. (2017)	12.01	2.69	16	13.91	2.33	16	1.2%	-0.74 [-1.46, -0.02]
Miller et al. (2002)	423.68	140.6	13	446.9	154.62	13	1.2%	-0.15 [-0.92, 0.62]
Moreira et al. (2017) (WT1)	12.5	2	30	13.8	2.9	30	1.4%	-0.52 [-1.03, -0.00]
Moreira et al. (2017) (WT2)	12.9	2.5	30	12.6	2.6	26	1.4%	0.12 [-0.41, 0.64]
Neiva et al. (2018)	8.36	3.09	15	9.68	3.6	15	1.2%	-0.38 [-1.11, 0.34]
Poyhonen et al. (2002)	-123.83	18.83	12	-110	12.5	12	1.1%	-0.84 [-1.68, 0.01]
Reichert et al. (2016) (WT1)	16.53	3.31	13	24.08	5.43	13	1.0%	-1.63 [-2.53, -0.72]
Reichert et al. (2016) (WT2)	16.61	5.11	12	24.46	6.76	12	1.1%	-1.26 [-2.16, -0.37]
Reichert et al. (2018) (WT1)	18.08	1.36	12	23.7	1.64	12	0.7%	-3.60 [-4.97, -2.23]
Reichert et al. (2018) (WT2)	18.92	1.48	12	23.84	2.32	12	0.9%	-2.44 [-3.54, -1.34]
Reichert et al. (2018) (WT3)	19.04	1.34	13	22.86	1.42	13	0.9%	-2.68 [-3.78, -1.58]
Robinson et al. (2004)	105.37	4.03	16	141.53	4.33	16	0.3%	-8.43 [-10.74, -6.12]
Sanders et al. (2013)	12.39	3.42	48	16.8	4.49	43	1.4%	-1.10 [-1.55, -0.66]
Seyedjafari et al. (2017)	13.77	3.28	15	28.5	5.99	15	0.9%	-2.97 [-4.05, -1.89]
Seynnes et al. (2002)	6.5	16.35	9	5.2	17.6	9	1.0%	0.07 [-0.85, 1.00]
Tsourlou et al. (2006)	33.45	2.06	12	41.23	2.04	12	0.7%	-3.66 [-5.05, -2.28]
Vale et al. (2020)	12.75	1.98	26	16.35	2.05	26	1.3%	-1.76 [-2.41, -1.11]
White & Smith (1999)	64.56	24.3	11	68.79	24.84	11	1.1%	-0.17 [-1.00, 0.67]
Subtotal (95% CI)			**546**			**537**	**32.5%**	**-0.97 [-1.31, -0.64]**
Heterogeneity: Tau² = 0.67; Chi² = 174.49, df = 28 (P < 0.00001); I² = 84%								
Test for overall effect: Z = 5.68 (P < 0.00001)								
Total (95% CI)			**1790**			**1753**	**100.0%**	**-0.66 [-0.81, -0.51]**
Heterogeneity: Tau² = 0.37; Chi² = 377.30, df = 82 (P < 0.00001); I² = 78%								
Test for overall effect: Z = 8.42 (P < 0.00001)								
Test for subgroup differences: Chi² = 14.09, df = 6 (P = 0.03), I² = 57.4%								

Figure 2. Forest plot of comparison for healthy population. The center of each square represents the standard mean difference for individual trials, and the corresponding horizontal line stands for 95% confidence interval (CI). The diamonds represent pooled results.

Adults with chronic diseases

Considering the 36 studies focusing on a population with a chronic disease, 6 articles compared different types of WT (of which 2 also included a CG), 11 studies compared WT with LT (where 3 also included a CG), 14 articles compared WT with a CG, 1 study compared WT with LT and WLT, and 4 studies used no comparison (only WT). It was established that the most frequent duration of the programs was 12 weeks (39% of the studies), especially on heart diseases and diabetes mellitus articles. Overall, in adults with chronic diseases, the benefits were significant, mainly for the QoL and balance, besides in strength, pain, and gait. The studies were grouped according to disease for further analysis, specifically, musculoskeletal diseases (fibromyalgia and bone diseases), heart diseases (coronary artery disease, heart failure, hypertension, and stroke), diabetes mellitus, multiple sclerosis, and Parkinson's disease.

Table 2. Effects of water-based activities on adults with chronic disease.

Author	**Subjects**	**Population**	**Intervention Period**	**Design**	**Intervention**	**Parameters Assessed**
Andrade et al. (2018)	54 F (47.5 y)	Fibromyalgia	16 weeks + 16 weeks Detraining [2/week]	RCT	WT: 45′ intervention CG: without intervention	Pain, Quality of Life
Andrade et al. (2017)	54 F (47.5 y)	Fibromyalgia	16 weeks [2/week]	RCT	WT: 10′ W + 30′ MW + 5′ Str CG: without intervention	Anthropometrics, Cardiorespiratory Fitness
Tomas-Carus et al. (2009)	30 F (50.8 y)	Fibromyalgia	32 weeks [3/week]	RCT	WT: 10′ W + 10′ AT + 20′ ET + 10′ AT + 10′ Str CG: without intervention	Balance, Quality of Life, Strength
Munguía-Izquierdo & Legaz-Arrese (2007)	60 F (48 y)	Fibromyalgia	16 weeks [3/week]	RCT	WT: 10′ W + 10-20′ ET + 20-30′ AT + 10′ Str CG: without intervention	Pain
Tomas-Carus et al. (2007)	34 F (51 y)	Fibromyalgia	12 weeks + 12 weeks Detraining [3/week]	RCT	WT: 10′ W + 10′ AT + 20′ ET + 10′ AT + 10′ Str CG: without intervention	Balance, Cardiorespiratory Fitness, Flexibility, Quality of Life, Strength
Cuesta-Vargas et al. (2012)	58 F/M (38.2 y)	Low Back Pain	15 weeks [3/week]	RCT	WT_1: 30′ intervention+ 30′ MW Deep Water Running WT_2: 30′ intervention	Pain
Suomi et al. (1997)	27 F (57.1 y)	Arthritis	6 weeks [3/week]	RCT	WT: ND CG: without intervention	Flexibility, Strength
Irandoust & Taheri (2015)	32 M (68 y)	Low Back Pain	12 weeks [3/week]	RCT	WT: 10′ W + 40′ MW + 10′ Str CG: without intervention	Anthropometrics
Pires et al. (2014)	55 F/M (50.95 y)	Low Back Pain	6 weeks [2/week]	RCT	WT: 30-50′ intervention + 90′ MW CG: 30-50′ intervention	Pain

Table 2. Continued.

Author	**Subjects**	**Population**	**Intervention Period**	**Design**	**Intervention**	**Parameters Assessed**
Baena-Beato et al. (2013)	25 F + 29 M (48.8 y)	Low Back Pain	8 weeks [2-3/week]	Non-RCT	WT_1(2/week): 10′ W + 15-20′ RT + 20-25′ AT + 10′ Str WT_2(3 /week): 10′ W + 15-20′ RT + 20-25′ AT + 10′ Str CG: without intervention	Anthropometrics, Cardiorespiratory Fitness, Flexibility, Pain, Quality of Life, Strength
Yalfani et al. (2020)	24 F (24.92 y)	Low Back Pain	8 weeks [3/week]	RCT	WT: 15’ W + 50’ MW + 10’ Str LT: 15’ W + 50’ MW + 10’ Str	Balance, Pain
Arnold & Faulkner (2010)	79 F/M (74.46 y)	Osteoarthritis	11 weeks [2-3/week]	RCT	WT_1(3/week): 45′ intervention + 30′ PT WT_2(2/week): 45′ intervention CG: without intervention	Balance, Cardiorespiratory Fitness, Strength
Bressel et al. (2014)	16 F + 2 M (64.5 y)	Osteoarthritis	6 weeks [ND]	RCT	WT: 30′ intervention	Balance, Pain, Strength
Moreira et al. (2020)	120 F/M (71.24 y)	Musculoskeletal disorders (osteoarthritis, rheumatic arthritis, fibromyalgia, sciatic back pain, or other chronic low back pain)	16 weeks [2/week]	RCT	WT: 5’ W + 40’ MW + Str CG: without intervention	Balance, Flexibility, Pain, Quality of life, Strength
Volaklis et al. (2007)	34 F/M (54 y)	Coronary Artery Disease	16 weeks [4/week]	RCT	WT: 10′ W + 30-40′ MW + 10′ Str LT: 10′ W + 30-40′ MW + 10′ Str CG: without intervention	Anthropometrics, Cardiorespiratory Fitness, Lipid Profile, Strength

Table 2. Continued.

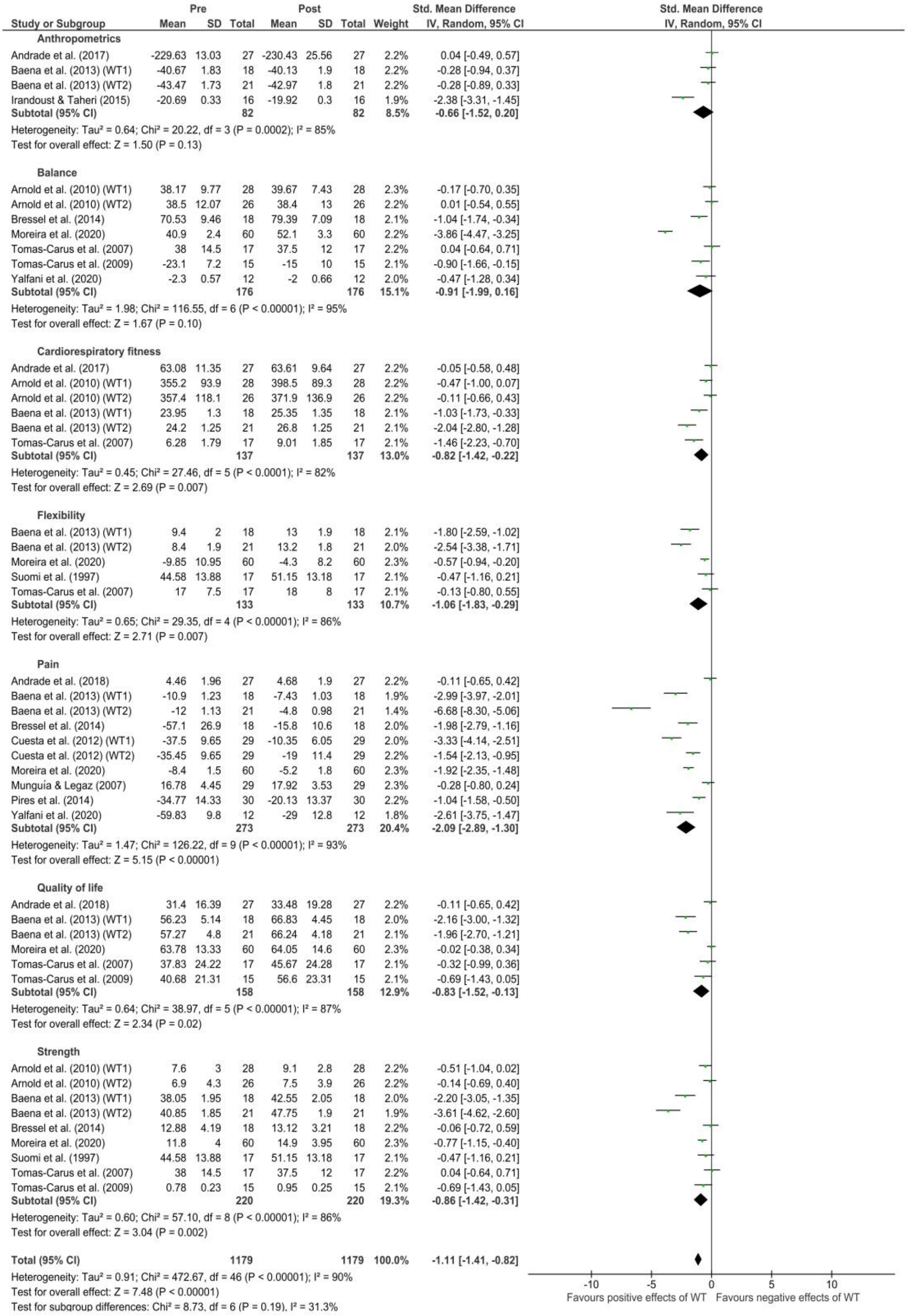
Author	**Subjects**	**Population**	**Intervention Period**	**Design**	**Intervention**	**Parameters Assessed**
Tokmakidis et al. (2008)	21 M (51.6 y)	Coronary Artery Disease	16 weeks + 16 weeks Detraining + 16 weeks Retraining [4/week]	RCT	WT: 10′ W + 5′ Str + 50′ MW + 10′ Str CG: without intervention	Anthropometrics, Cardiorespiratory Fitness
Arca et al. (2013)	52 F (64 y)	Hypertension	12 weeks [3/week]	RCT	WT: 10′ W + 10′ Str + 20′ MW + 10′ Str LT: 10′ W + 10′ Str + 20′ MW + 10′ Str CG: without intervention	Anthropometrics, Lipid Profile
Ruangthai et al. (2020)	30 F + 11 M (69.2 y)	Hypertension	12 weeks [3/week]	RCT	WT: 10’ W + 40’ MW + 10’ Str LT: 10’ W + 40’ MW + 10’ Str CG: without intervention	Anthropometrics, Lipid Profile, Quality of Life
Silva et al. (2017)	29 F/M (53 y)	Hypertension	12 weeks [2/week]	RCLT	WT_1Hy: 5′ W + 40′ MW + 5′ Str WT_2NHy: 5′ W + 40′ MW + 5′ Str	Balance
Lee et al. (2018)	32 F/M (60.62 y)	Stroke	4 weeks [5/week]	RCT	WT: 5′ W + 20′ MW + 5′ Str LT: 5′ W + 20′ MW + 5′ Str	Balance, Cardiorespiratory Fitness, Quality of Life, Strength
Zhang et al. (2016)	36 F/M (55.5 y)	Stroke	8 weeks [5/week]	RCT	WT: 5′ W + 35′ MW LT: 5′ W + 35′ MW	Strength
Aidar et al. (2017)	17 F + 19 M (52.25 y)	Stroke	12 weeks [2/week]	RCT	WT: 45-60′ intervention CG: without intervention	Balance

Table 2. Continued.

Author	Subjects	Population	Intervention Period	Design	Intervention	Parameters Assessed
Cruz (2020)	9 F +20 M (47.2 y)	Stroke	4 weeks [3/week]	RCT	WT: 10’ W + 25’ MW + 10’ Str	Balance
Matsumoto et al. (2016)	32 F + 88 M (62.8 y)	Stroke	12 weeks [2/week]	Non-RCT	WT: 5′ W + 20′ MW + 5′ Str / RT CG: RT	Cardiorespiratory Fitness, Quality of Life
Zhu et al. (2017)	46 F/M (66 y)	Parkinson	6 weeks [5/week]	RCT	WT$_1$: 5′ W + 30′ MW + 5′ Str WT$_2$(obstacles): 5′ W + 30′ MW + 5′ Str	Balance, Gait, Quality of Life
Ayán & Cancela (2012b)	21 F/M (70.4 y)	Parkinson	12 weeks [2/week]	Non-RCT	WT$_1$: 60′ intervention WT$_2$: 60′ RT	Balance, Quality of Life
Cruz (2017)	17 F + 13 M (67.17 y)	Parkinson	10 weeks [2/week]	RCLT	WT: 5′ W + 35′ MW + 5′ Str LT: 10′ W + 25′ MW + 10′ Str	Balance, Gait, Pain, Quality of life
Ayán & Cancela (2012a)	16 F/M (65.30 y)	Parkinson	12 weeks [2/week]	RCT	WT: 10′ W + 35′ MW + 10′ Str	Balance, Cardiorespiratory Fitness, Flexibility, Strength, Quality of Life

AT Aerobic Training, *CG* Control Group, *ET* Endurance Training, *F* Female, *HY* Hypertensive, *LT* Land-based Training, *M* Male, *MW* Main Workout, *ND* Not Defined, *NHY* Non-Hypertensive, *Non-RCT* Non-Randomized Controlled Trial, *PT* Physical Therapy, *RCT* Randomized Controlled Trial, *RCLT* Randomized clinical trial, *RT* Rehabilitation Therapy, *Str* Stretching, *W* Warm-up, *WT* Water-based Training, *y* years old

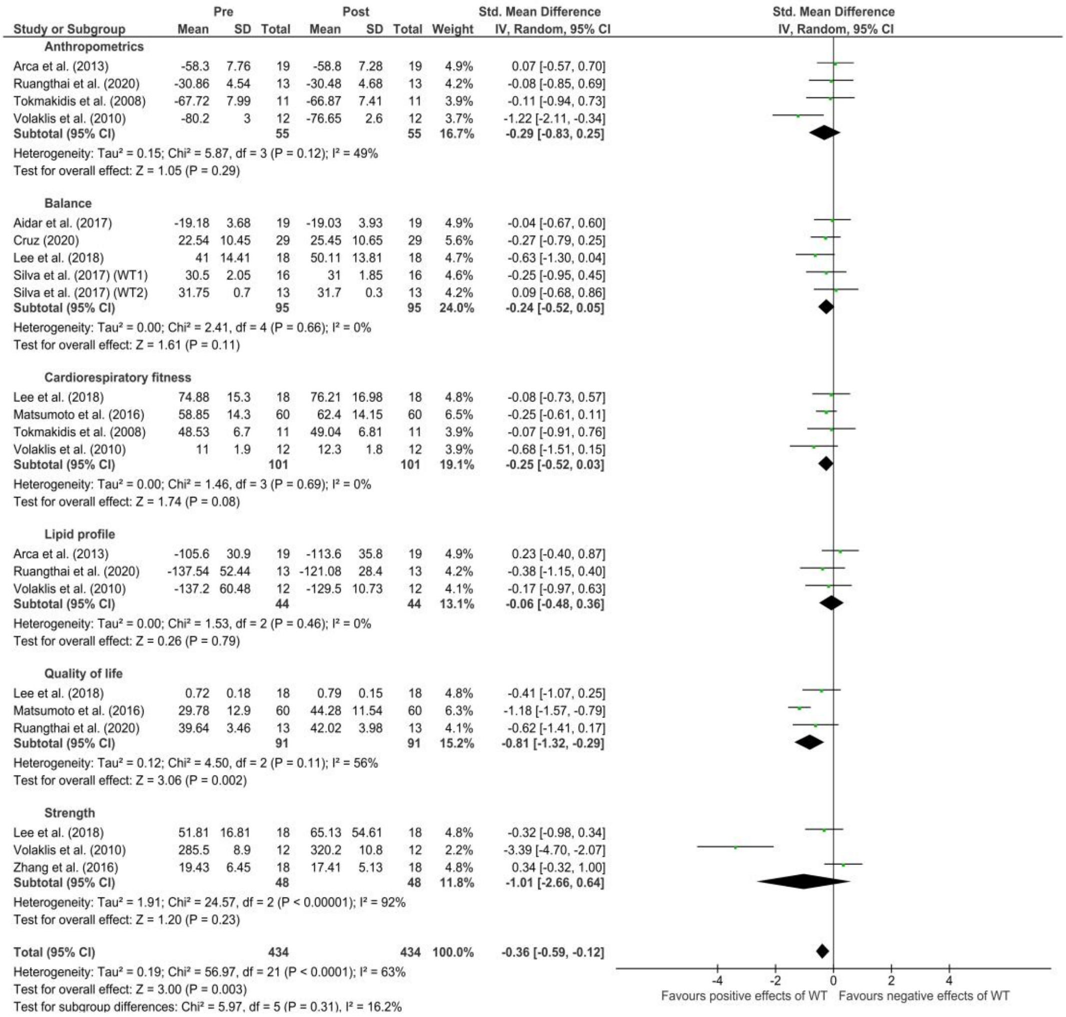
Concerning musculoskeletal diseases (Figure 3), we observed that WT was beneficial in fibromyalgia, improving balance and cardiorespiratory fitness, especially in the studies of Tomas-Carus et al. (2007) and Tomas-Carus et al. (2009) (large effect). Additionally, we observed that aquatic exercise was ineffective at improving anthropometry in individuals with fibromyalgia (Andrade et al., 2017). Regarding adults with bone diseases (Figure 3) (i.e., osteoarthritis and low back pain), several articles reported substantial progress mainly in the relief of pain [large effect (Baena-Beato et al., 2013; Bressel et al., 2014; Cuesta-Vargas et al., 2012; Moreira et al., 2020; Pires et al., 2014; Yalfani et al., 2020)], balance [large effect (Bressel et al., 2014; Moreira et al., 2020)], flexibility [medium (Moreira et al., 2020) and large effect (Baena-Beato et al., 2013)] and strength [medium (Moreira et al., 2020) and large effect (Baena-Beato et al., 2013)], but also in QoL [large effect (Baena-Beato et al., 2013)], anthropometry [large effect (Irandoust & Taheri, 2015)], and cardiorespiratory fitness [large effect (Baena-Beato et al., 2013)]. Furthermore, large intervention effects were found in pain, cardiorespiratory fitness, flexibility, QoL and strength in the overall analysis of musculoskeletal diseases.



	Pre			Post				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Anthropometrics								
Andrade et al. (2017)	-229.63	13.03	27	-230.43	25.56	27	2.2%	0.04 [-0.49, 0.57]
Baena et al. (2013) (WT1)	-40.67	1.83	18	-40.13	1.9	18	2.2%	-0.28 [-0.94, 0.37]
Baena et al. (2013) (WT2)	-43.47	1.73	21	-42.97	1.8	21	2.2%	-0.28 [-0.89, 0.33]
Irandoust & Taheri (2015)	-20.69	0.33	16	-19.92	0.3	16	1.9%	-2.38 [-3.31, -1.45]
Subtotal (95% CI)			**82**			**82**	**8.5%**	**-0.66 [-1.52, 0.20]**
Heterogeneity: Tau² = 0.64; Chi² = 20.22, df = 3 (P = 0.0002); I² = 85%								
Test for overall effect: Z = 1.50 (P = 0.13)								
Balance								
Arnold et al. (2010) (WT1)	38.17	9.77	28	39.67	7.43	28	2.3%	-0.17 [-0.70, 0.35]
Arnold et al. (2010) (WT2)	38.5	12.07	26	38.4	13	26	2.2%	0.01 [-0.54, 0.55]
Bressel et al. (2014)	70.53	9.46	18	79.39	7.09	18	2.1%	-1.04 [-1.74, -0.34]
Moreira et al. (2020)	40.9	2.4	60	52.1	3.3	60	2.2%	-3.86 [-4.47, -3.25]
Tomas-Carus et al. (2007)	38	14.5	17	37.5	12	17	2.2%	0.04 [-0.64, 0.71]
Tomas-Carus et al. (2009)	-23.1	7.2	15	-15	10	15	2.1%	-0.90 [-1.66, -0.15]
Yalfani et al. (2020)	-2.3	0.57	12	-2	0.66	12	2.0%	-0.47 [-1.28, 0.34]
Subtotal (95% CI)			**176**			**176**	**15.1%**	**-0.91 [-1.99, 0.16]**
Heterogeneity: Tau² = 1.98; Chi² = 116.55, df = 6 (P < 0.00001); I² = 95%								
Test for overall effect: Z = 1.67 (P = 0.10)								
Cardiorespiratory fitness								
Andrade et al. (2017)	63.08	11.35	27	63.61	9.64	27	2.2%	-0.05 [-0.58, 0.48]
Arnold et al. (2010) (WT1)	355.2	93.9	28	398.5	89.3	28	2.2%	-0.47 [-1.00, 0.07]
Arnold et al. (2010) (WT2)	357.4	118.1	26	371.9	136.9	26	2.2%	-0.11 [-0.66, 0.43]
Baena et al. (2013) (WT1)	23.95	1.3	18	25.35	1.35	18	2.1%	-1.03 [-1.73, -0.33]
Baena et al. (2013) (WT2)	24.2	1.25	21	26.8	1.25	21	2.1%	-2.04 [-2.80, -1.28]
Tomas-Carus et al. (2007)	6.28	1.79	17	9.01	1.85	17	2.1%	-1.46 [-2.23, -0.70]
Subtotal (95% CI)			**137**			**137**	**13.0%**	**-0.82 [-1.42, -0.22]**
Heterogeneity: Tau² = 0.45; Chi² = 27.46, df = 5 (P < 0.0001); I² = 82%								
Test for overall effect: Z = 2.69 (P = 0.007)								
Flexibility								
Baena et al. (2013) (WT1)	9.4	2	18	13	1.9	18	2.1%	-1.80 [-2.59, -1.02]
Baena et al. (2013) (WT2)	8.4	1.9	21	13.2	1.8	21	2.0%	-2.54 [-3.38, -1.71]
Moreira et al. (2020)	-9.85	10.95	60	-4.3	8.2	60	2.3%	-0.57 [-0.94, -0.20]
Suomi et al. (1997)	44.58	13.88	17	51.15	13.18	17	2.1%	-0.47 [-1.16, 0.21]
Tomas-Carus et al. (2007)	17	7.5	17	18	8	17	2.1%	-0.13 [-0.80, 0.55]
Subtotal (95% CI)			**133**			**133**	**10.7%**	**-1.06 [-1.83, -0.29]**
Heterogeneity: Tau² = 0.65; Chi² = 29.35, df = 4 (P < 0.00001); I² = 86%								
Test for overall effect: Z = 2.71 (P = 0.007)								
Pain								
Andrade et al. (2018)	4.46	1.96	27	4.68	1.9	27	2.2%	-0.11 [-0.65, 0.42]
Baena et al. (2013) (WT1)	-10.9	1.23	18	-7.43	1.03	18	1.9%	-2.99 [-3.97, -2.01]
Baena et al. (2013) (WT2)	-12	1.13	21	-4.8	0.98	21	1.4%	-6.68 [-8.30, -5.06]
Bressel et al. (2014)	-57.1	26.9	18	-15.8	10.6	18	2.0%	-1.98 [-2.79, -1.16]
Cuesta et al. (2012) (WT1)	-37.5	9.65	29	-10.35	6.05	29	2.0%	-3.33 [-4.14, -2.51]
Cuesta et al. (2012) (WT2)	-35.45	9.65	29	-19	11.4	29	2.2%	-1.54 [-2.13, -0.95]
Moreira et al. (2020)	-8.4	1.5	60	-5.2	1.8	60	2.3%	-1.92 [-2.35, -1.48]
Munguía & Legaz (2007)	16.78	4.45	29	17.92	3.53	29	2.3%	-0.28 [-0.80, 0.24]
Pires et al. (2014)	-34.77	14.33	30	-20.13	13.37	30	2.2%	-1.04 [-1.58, -0.50]
Yalfani et al. (2020)	-59.83	9.8	12	-29	12.8	12	1.8%	-2.61 [-3.75, -1.47]
Subtotal (95% CI)			**273**			**273**	**20.4%**	**-2.09 [-2.89, -1.30]**
Heterogeneity: Tau² = 1.47; Chi² = 126.22, df = 9 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 5.15 (P < 0.00001)								
Quality of life								
Andrade et al. (2018)	31.4	16.39	27	33.48	19.28	27	2.2%	-0.11 [-0.65, 0.42]
Baena et al. (2013) (WT1)	56.23	5.14	18	66.83	4.45	18	2.0%	-2.16 [-3.00, -1.32]
Baena et al. (2013) (WT2)	57.27	4.8	21	66.24	4.18	21	2.1%	-1.96 [-2.70, -1.21]
Moreira et al. (2020)	63.78	13.33	60	64.05	14.6	60	2.3%	-0.02 [-0.38, 0.34]
Tomas-Carus et al. (2007)	37.83	24.22	17	45.67	24.28	17	2.1%	-0.32 [-0.99, 0.36]
Tomas-Carus et al. (2009)	40.68	21.31	15	56.6	23.31	15	2.1%	-0.69 [-1.43, 0.05]
Subtotal (95% CI)			**158**			**158**	**12.9%**	**-0.83 [-1.52, -0.13]**
Heterogeneity: Tau² = 0.64; Chi² = 38.97, df = 5 (P < 0.00001); I² = 87%								
Test for overall effect: Z = 2.34 (P = 0.02)								
Strength								
Arnold et al. (2010) (WT1)	7.6	3	28	9.1	2.8	28	2.2%	-0.51 [-1.04, 0.02]
Arnold et al. (2010) (WT2)	6.9	4.3	26	7.5	3.9	26	2.2%	-0.14 [-0.69, 0.40]
Baena et al. (2013) (WT1)	38.05	1.95	18	42.55	2.05	18	2.0%	-2.20 [-3.05, -1.35]
Baena et al. (2013) (WT2)	40.85	1.85	21	47.75	1.9	21	1.9%	-3.61 [-4.62, -2.60]
Bressel et al. (2014)	12.88	4.19	18	13.12	3.21	18	2.2%	-0.06 [-0.72, 0.59]
Moreira et al. (2020)	11.8	4	60	14.9	3.95	60	2.3%	-0.77 [-1.15, -0.40]
Suomi et al. (1997)	44.58	13.88	17	51.15	13.18	17	2.1%	-0.47 [-1.16, 0.21]
Tomas-Carus et al. (2007)	38	14.5	17	37.5	12	17	2.2%	0.04 [-0.64, 0.71]
Tomas-Carus et al. (2009)	0.78	0.23	15	0.95	0.25	15	2.1%	-0.69 [-1.43, 0.05]
Subtotal (95% CI)			**220**			**220**	**19.3%**	**-0.86 [-1.42, -0.31]**
Heterogeneity: Tau² = 0.60; Chi² = 57.10, df = 8 (P < 0.00001); I² = 86%								
Test for overall effect: Z = 3.04 (P = 0.002)								
Total (95% CI)			**1179**			**1179**	**100.0%**	**-1.11 [-1.41, -0.82]**
Heterogeneity: Tau² = 0.91; Chi² = 472.67, df = 46 (P < 0.00001); I² = 90%								
Test for overall effect: Z = 7.48 (P < 0.00001)								
Test for subgroup differences: Chi² = 8.73, df = 6 (P = 0.19), I² = 31.3%								

Figure 3. Forest plot of comparison for Musculoskeletal diseases - Fibromyalgia and Bone diseases. The center of each square represents the standard mean difference for individual trials, and the corresponding horizontal line stands for 95% confidence interval (CI). The diamonds represent pooled results.

Among heart diseases (Figure 4), using aquatic exercise among adults with coronary artery disease led to large increases in strength [large effect (Volaklis et al., 2007)] and anthropometrics [large effect (Volaklis et al., 2007)]. Regarding hypertension, we found that aquatic programs were slightly effective for improving QoL [medium effect (Ruangthai et al., 2020)], but not for anthropometrics (Arca et al., 2013; Ruangthai et al., 2020) and lipid profile (Arca et al., 2013; Ruangthai et al., 2020). In people with stroke, a significantly improved QoL [large effect (Matsumoto et al., 2016)] were reported. The overall results suggested large improvements in QoL in heart diseases. Nevertheless, despite the significant results in these two variables, this group of diseases only induced small effects on health status and physical fitness.

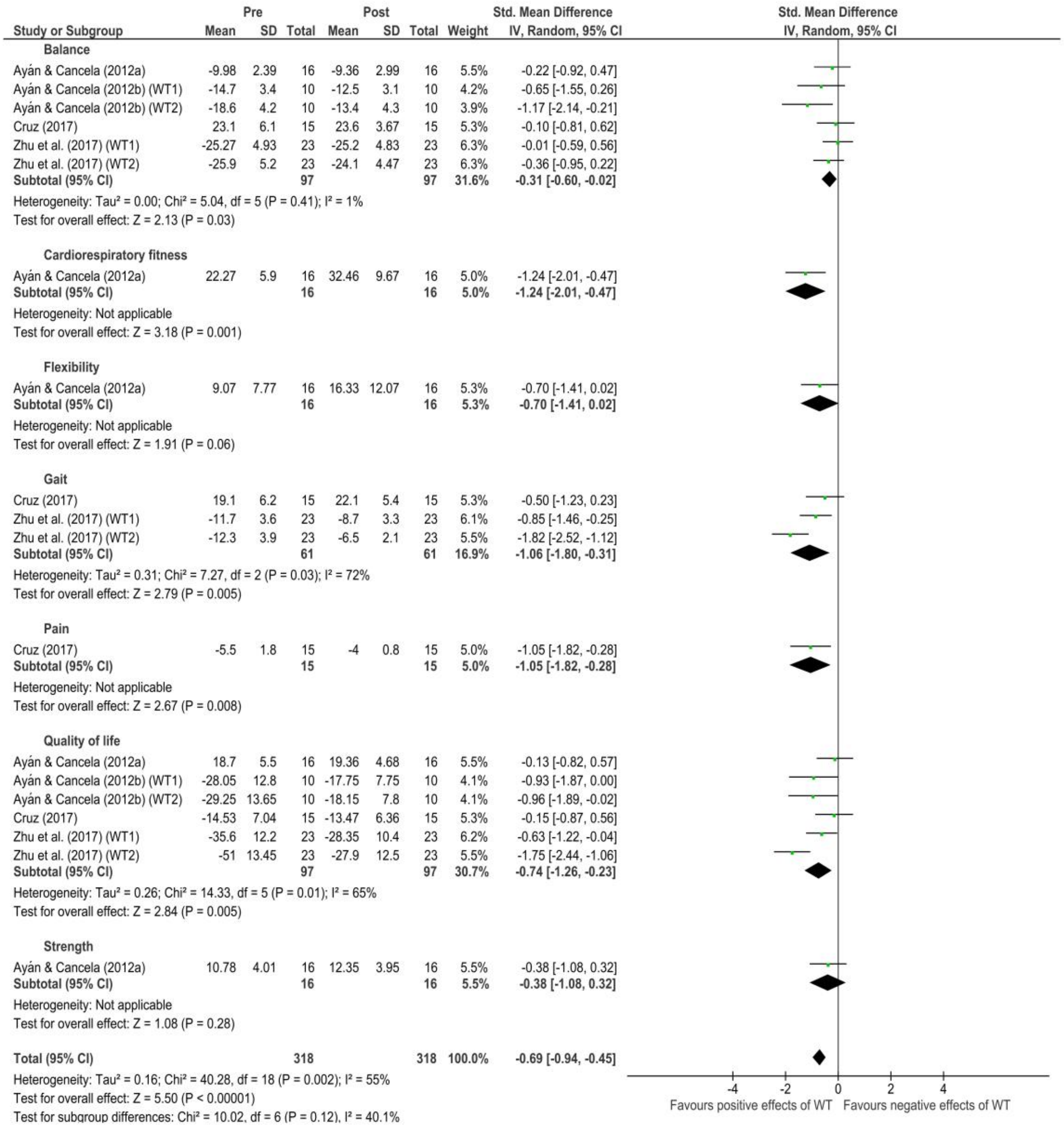


	Pre			Post				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Anthropometrics								
Arca et al. (2013)	-58.3	7.76	19	-58.8	7.28	19	4.9%	0.07 [-0.57, 0.70]
Ruangthai et al. (2020)	-30.86	4.54	13	-30.48	4.68	13	4.2%	-0.08 [-0.85, 0.69]
Tokmakidis et al. (2008)	-67.72	7.99	11	-66.87	7.41	11	3.9%	-0.11 [-0.94, 0.73]
Volaklis et al. (2010)	-80.2	3	12	-76.65	2.6	12	3.7%	-1.22 [-2.11, -0.34]
Subtotal (95% CI)			**55**			**55**	**16.7%**	**-0.29 [-0.83, 0.25]**
Heterogeneity: Tau² = 0.15; Chi² = 5.87, df = 3 (P = 0.12); I² = 49%								
Test for overall effect: Z = 1.05 (P = 0.29)								
Balance								
Aidar et al. (2017)	-19.18	3.68	19	-19.03	3.93	19	4.9%	-0.04 [-0.67, 0.60]
Cruz (2020)	22.54	10.45	29	25.45	10.65	29	5.6%	-0.27 [-0.79, 0.25]
Lee et al. (2018)	41	14.41	18	50.11	13.81	18	4.7%	-0.63 [-1.30, 0.04]
Silva et al. (2017) (WT1)	30.5	2.05	16	31	1.85	16	4.6%	-0.25 [-0.95, 0.45]
Silva et al. (2017) (WT2)	31.75	0.7	13	31.7	0.3	13	4.2%	0.09 [-0.68, 0.86]
Subtotal (95% CI)			**95**			**95**	**24.0%**	**-0.24 [-0.52, 0.05]**
Heterogeneity: Tau² = 0.00; Chi² = 2.41, df = 4 (P = 0.66); I² = 0%								
Test for overall effect: Z = 1.61 (P = 0.11)								
Cardiorespiratory fitness								
Lee et al. (2018)	74.88	15.3	18	76.21	16.98	18	4.8%	-0.08 [-0.73, 0.57]
Matsumoto et al. (2016)	58.85	14.3	60	62.4	14.15	60	6.5%	-0.25 [-0.61, 0.11]
Tokmakidis et al. (2008)	48.53	6.7	11	49.04	6.81	11	3.9%	-0.07 [-0.91, 0.76]
Volaklis et al. (2010)	11	1.9	12	12.3	1.8	12	3.9%	-0.68 [-1.51, 0.15]
Subtotal (95% CI)			**101**			**101**	**19.1%**	**-0.25 [-0.52, 0.03]**
Heterogeneity: Tau² = 0.00; Chi² = 1.46, df = 3 (P = 0.69); I² = 0%								
Test for overall effect: Z = 1.74 (P = 0.08)								
Lipid profile								
Arca et al. (2013)	-105.6	30.9	19	-113.6	35.8	19	4.9%	0.23 [-0.40, 0.87]
Ruangthai et al. (2020)	-137.54	52.44	13	-121.08	28.4	13	4.2%	-0.38 [-1.15, 0.40]
Volaklis et al. (2010)	-137.2	60.48	12	-129.5	10.73	12	4.1%	-0.17 [-0.97, 0.63]
Subtotal (95% CI)			**44**			**44**	**13.1%**	**-0.06 [-0.48, 0.36]**
Heterogeneity: Tau² = 0.00; Chi² = 1.53, df = 2 (P = 0.46); I² = 0%								
Test for overall effect: Z = 0.26 (P = 0.79)								
Quality of life								
Lee et al. (2018)	0.72	0.18	18	0.79	0.15	18	4.8%	-0.41 [-1.07, 0.25]
Matsumoto et al. (2016)	29.78	12.9	60	44.28	11.54	60	6.3%	-1.18 [-1.57, -0.79]
Ruangthai et al. (2020)	39.64	3.46	13	42.02	3.98	13	4.1%	-0.62 [-1.41, 0.17]
Subtotal (95% CI)			**91**			**91**	**15.2%**	**-0.81 [-1.32, -0.29]**
Heterogeneity: Tau² = 0.12; Chi² = 4.50, df = 2 (P = 0.11); I² = 56%								
Test for overall effect: Z = 3.06 (P = 0.002)								
Strength								
Lee et al. (2018)	51.81	16.81	18	65.13	54.61	18	4.8%	-0.32 [-0.98, 0.34]
Volaklis et al. (2010)	285.5	8.9	12	320.2	10.8	12	2.2%	-3.39 [-4.70, -2.07]
Zhang et al. (2016)	19.43	6.45	18	17.41	5.13	18	4.8%	0.34 [-0.32, 1.00]
Subtotal (95% CI)			**48**			**48**	**11.8%**	**-1.01 [-2.66, 0.64]**
Heterogeneity: Tau² = 1.91; Chi² = 24.57, df = 2 (P < 0.00001); I² = 92%								
Test for overall effect: Z = 1.20 (P = 0.23)								
Total (95% CI)			**434**			**434**	**100.0%**	**-0.36 [-0.59, -0.12]**
Heterogeneity: Tau² = 0.19; Chi² = 56.97, df = 21 (P < 0.0001); I² = 63%								
Test for overall effect: Z = 3.00 (P = 0.003)								
Test for subgroup differences: Chi² = 5.97, df = 5 (P = 0.31), I² = 16.2%								

Figure 4. Forest plot of comparison for Heart diseases - Coronary artery disease, Hypertension and Stroke. The center of each square represents the standard mean difference for individual trials, and the corresponding horizontal line stands for 95% confidence interval (CI). The diamonds represent pooled results.

In individuals with diabetes mellitus, we can infer that WT caused improvements in several physical fitness and health-related outcomes, specifically balance (Delevatti et al., 2015), and QoL (Delevatti et al., 2017). In addition, there were also positive effects on the lipid profile, especially on glucose (Delevatti et al., 2016), and in BP (Delevatti et al., 2015). In multiple sclerosis, the QoL (Garopoulou et al., 2014; Kargarfard et al., 2012), and balance (Kalron et al., 2015), proved to be the parameters that were most positively affected after these programs, although gait (Kalron et al., 2015) and fatigue (Kargarfard et al., 2012) also showed slight increases.

Among Parkinson's disease (Figure 5), it was mostly their levels of pain, gait, cardiorespiratory fitness and QoL [large effects (Ayán & Cancela, 2012a; Ayán & Cancela, 2012b; Cruz, 2017; Zhu et al., 2017)] that were enhanced after WT. Additionally, large improvements were found in cardiorespiratory fitness (Ayán & Cancela, 2012a), and balance (Ayán & Cancela, 2012b). In general, WT was responsible for producing medium effects in individuals with Parkinson's disease.



	Pre			Post				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Balance								
Ayán & Cancela (2012a)	-9.98	2.39	16	-9.36	2.99	16	5.5%	-0.22 [-0.92, 0.47]
Ayán & Cancela (2012b) (WT1)	-14.7	3.4	10	-12.5	3.1	10	4.2%	-0.65 [-1.55, 0.26]
Ayán & Cancela (2012b) (WT2)	-18.6	4.2	10	-13.4	4.3	10	3.9%	-1.17 [-2.14, -0.21]
Cruz (2017)	23.1	6.1	15	23.6	3.67	15	5.3%	-0.10 [-0.81, 0.62]
Zhu et al. (2017) (WT1)	-25.27	4.93	23	-25.2	4.83	23	6.3%	-0.01 [-0.59, 0.56]
Zhu et al. (2017) (WT2)	-25.9	5.2	23	-24.1	4.47	23	6.3%	-0.36 [-0.95, 0.22]
Subtotal (95% CI)			**97**			**97**	**31.6%**	**-0.31 [-0.60, -0.02]**
Heterogeneity: Tau² = 0.00; Chi² = 5.04, df = 5 (P = 0.41); I² = 1%								
Test for overall effect: Z = 2.13 (P = 0.03)								
Cardiorespiratory fitness								
Ayán & Cancela (2012a)	22.27	5.9	16	32.46	9.67	16	5.0%	-1.24 [-2.01, -0.47]
Subtotal (95% CI)			**16**			**16**	**5.0%**	**-1.24 [-2.01, -0.47]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 3.18 (P = 0.001)								
Flexibility								
Ayán & Cancela (2012a)	9.07	7.77	16	16.33	12.07	16	5.3%	-0.70 [-1.41, 0.02]
Subtotal (95% CI)			**16**			**16**	**5.3%**	**-0.70 [-1.41, 0.02]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.91 (P = 0.06)								
Gait								
Cruz (2017)	19.1	6.2	15	22.1	5.4	15	5.3%	-0.50 [-1.23, 0.23]
Zhu et al. (2017) (WT1)	-11.7	3.6	23	-8.7	3.3	23	6.1%	-0.85 [-1.46, -0.25]
Zhu et al. (2017) (WT2)	-12.3	3.9	23	-6.5	2.1	23	5.5%	-1.82 [-2.52, -1.12]
Subtotal (95% CI)			**61**			**61**	**16.9%**	**-1.06 [-1.80, -0.31]**
Heterogeneity: Tau² = 0.31; Chi² = 7.27, df = 2 (P = 0.03); I² = 72%								
Test for overall effect: Z = 2.79 (P = 0.005)								
Pain								
Cruz (2017)	-5.5	1.8	15	-4	0.8	15	5.0%	-1.05 [-1.82, -0.28]
Subtotal (95% CI)			**15**			**15**	**5.0%**	**-1.05 [-1.82, -0.28]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 2.67 (P = 0.008)								
Quality of life								
Ayán & Cancela (2012a)	18.7	5.5	16	19.36	4.68	16	5.5%	-0.13 [-0.82, 0.57]
Ayán & Cancela (2012b) (WT1)	-28.05	12.8	10	-17.75	7.75	10	4.1%	-0.93 [-1.87, 0.00]
Ayán & Cancela (2012b) (WT2)	-29.25	13.65	10	-18.15	7.8	10	4.1%	-0.96 [-1.89, -0.02]
Cruz (2017)	-14.53	7.04	15	-13.47	6.36	15	5.3%	-0.15 [-0.87, 0.56]
Zhu et al. (2017) (WT1)	-35.6	12.2	23	-28.35	10.4	23	6.2%	-0.63 [-1.22, -0.04]
Zhu et al. (2017) (WT2)	-51	13.45	23	-27.9	12.5	23	5.5%	-1.75 [-2.44, -1.06]
Subtotal (95% CI)			**97**			**97**	**30.7%**	**-0.74 [-1.26, -0.23]**
Heterogeneity: Tau² = 0.26; Chi² = 14.33, df = 5 (P = 0.01); I² = 65%								
Test for overall effect: Z = 2.84 (P = 0.005)								
Strength								
Ayán & Cancela (2012a)	10.78	4.01	16	12.35	3.95	16	5.5%	-0.38 [-1.08, 0.32]
Subtotal (95% CI)			**16**			**16**	**5.5%**	**-0.38 [-1.08, 0.32]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.08 (P = 0.28)								
Total (95% CI)			**318**			**318**	**100.0%**	**-0.69 [-0.94, -0.45]**
Heterogeneity: Tau² = 0.16; Chi² = 40.28, df = 18 (P = 0.002); I² = 55%								
Test for overall effect: Z = 5.50 (P < 0.00001)								
Test for subgroup differences: Chi² = 10.02, df = 6 (P = 0.12), I² = 40.1%								

Figure 5. Forest plot of comparison for Parkinson. The center of each square represents the standard mean difference for individual trials, and the corresponding horizontal line stands for 95% confidence interval (CI). The diamonds represent pooled results.

Risk of Bias

Overall, in randomized studies there was a dominance of the low risk in the different key criteria, both in studies applied to healthy adults (58%) and adults with chronic diseases (65%). However, there is a lack of information regarding the risk of bias in many articles, with 34% of the key criteria for healthy adults and 30% of the key criteria for adults with diseases having an unclear risk of bias. In studies of healthy adults, a high risk of bias was found in the incomplete outcome data (16%). Additionally, unclear risk of bias was shown to be common, especially concerning the blinding of participants and personnel (95%), allocation concealment (85%), and the blinding of outcome (68%). Regarding adults with chronic diseases, a high risk of bias was mainly observed for allocation concealment (19%) and random sequence generation (12.5%). Additionally, there was an unclear risk, particularly in the blinding of participants and personnel (78%), the blinding of outcome assessment (62.5%), and allocation concealment (53%) (Figures 6-9). In nonrandomized studies, in healthy adults the overall risk bias was mostly: moderate (43%), in bias due to selection of participants; low (28.5%) in bias due to confounding, due to deviations from intended interventions, due to missing data and in selection of the reported result; and serious (28.5%), in classifications of interventions. There was also a lack of information about the risk of bias in the domain of the bias in measurement of outcome. In adults with chronic diseases the overall risk of bias was: low (50%), with a preponderance in bias due to confounding, in classification of interventions, due to deviations intended interventions, due to missing data, in measurements of outcome and selection of the reported result; and moderate (50%), in bias due to selections of participants (Figures 10-13).

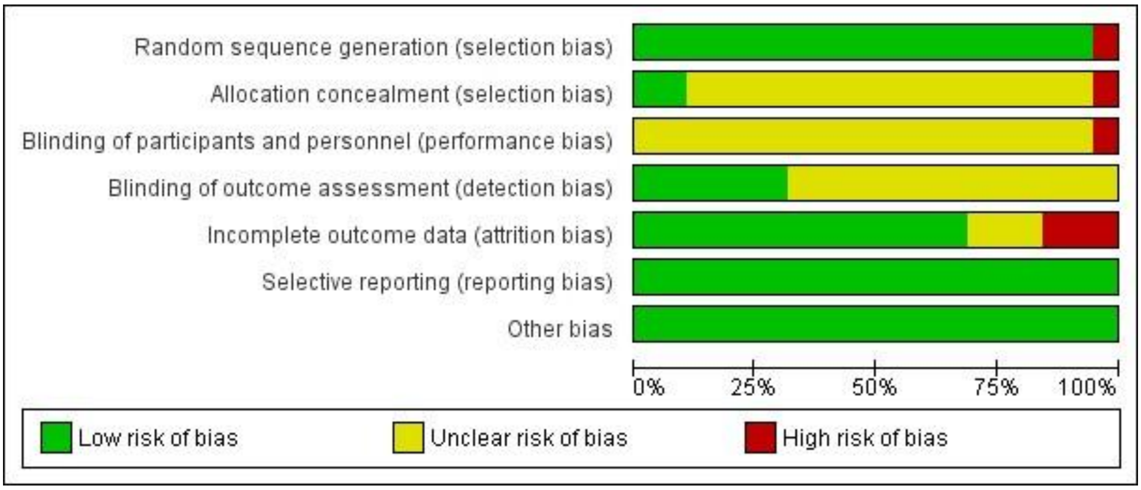
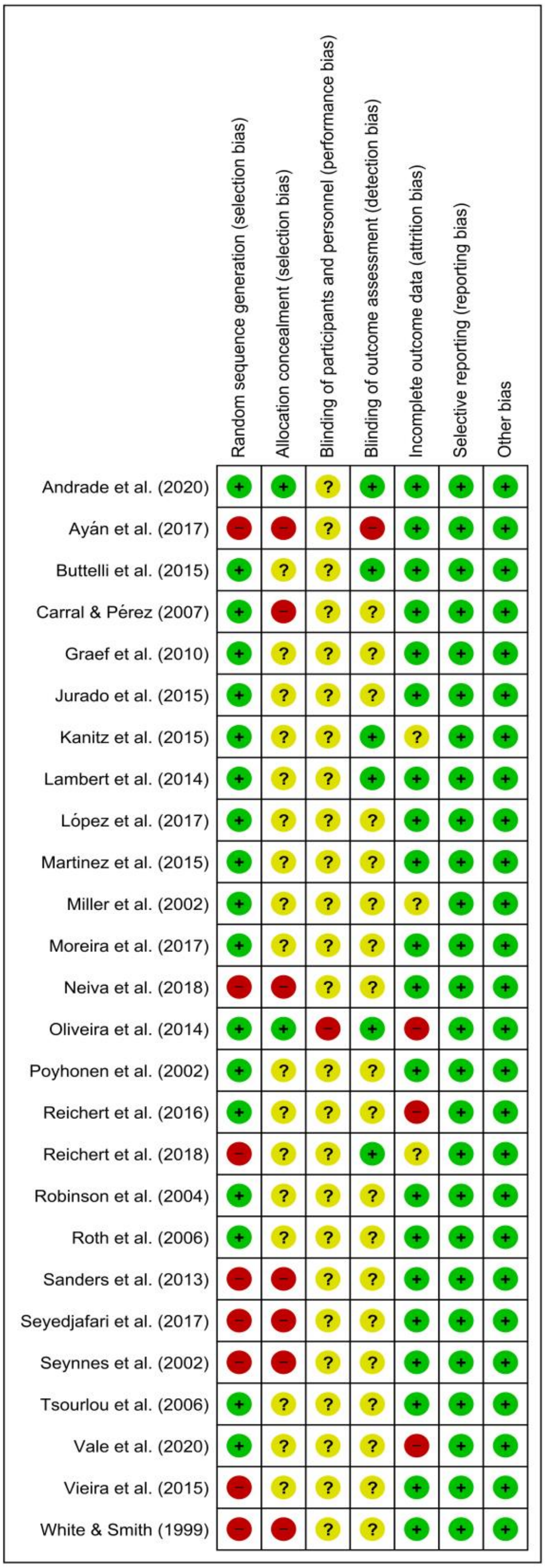


Figure 6. Risk-of-bias item presented as percentages across randomized studies for healthy population.



	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Andrade et al. (2020)	+	+	?	+	+	+	+
Ayán et al. (2017)	−	−	?	−	+	+	+
Buttelli et al. (2015)	+	?	?	+	+	+	+
Carral & Pérez (2007)	+	−	?	?	+	+	+
Graef et al. (2010)	+	?	?	?	+	+	+
Jurado et al. (2015)	+	?	?	?	+	+	+
Kanitz et al. (2015)	+	?	?	+	?	+	+
Lambert et al. (2014)	+	?	?	+	+	+	+
López et al. (2017)	+	?	?	?	+	+	+
Martinez et al. (2015)	+	?	?	?	+	+	+
Miller et al. (2002)	+	?	?	?	?	+	+
Moreira et al. (2017)	+	?	?	?	+	+	+
Neiva et al. (2018)	−	−	?	?	+	+	+
Oliveira et al. (2014)	+	+	−	+	−	+	+
Poyhonen et al. (2002)	+	?	?	?	+	+	+
Reichert et al. (2016)	+	?	?	?	−	+	+
Reichert et al. (2018)	−	?	?	+	?	+	+
Robinson et al. (2004)	+	?	?	?	+	+	+
Roth et al. (2006)	+	?	?	?	+	+	+
Sanders et al. (2013)	−	−	?	?	+	+	+
Seyedjafari et al. (2017)	−	−	?	?	+	+	+
Seynnes et al. (2002)	−	−	?	?	+	+	+
Tsourlou et al. (2006)	+	?	?	?	+	+	+
Vale et al. (2020)	+	?	?	?	−	+	+
Vieira et al. (2015)	−	?	?	?	+	+	+
White & Smith (1999)	−	−	?	?	+	+	+

Figure 7. Judgments about each risk-of-bias item for each randomized study for healthy population. + indicates low risk, ? indicates unclear risk, – indicates high risk.

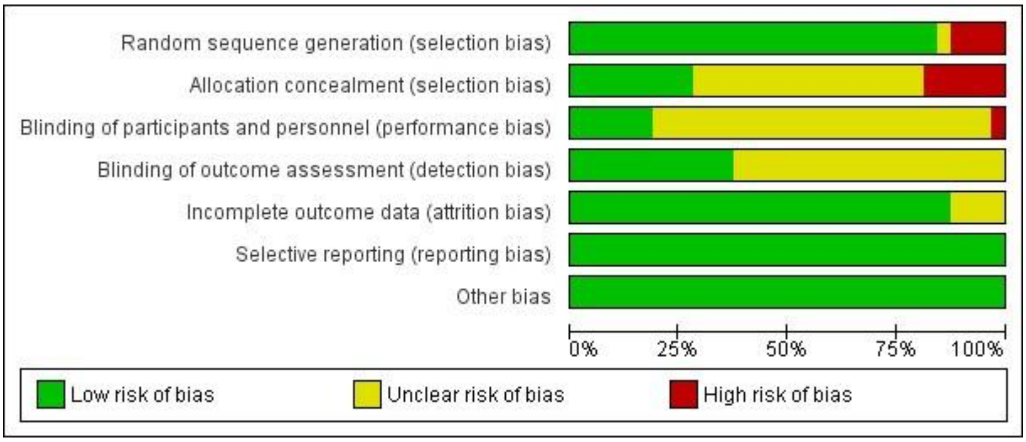
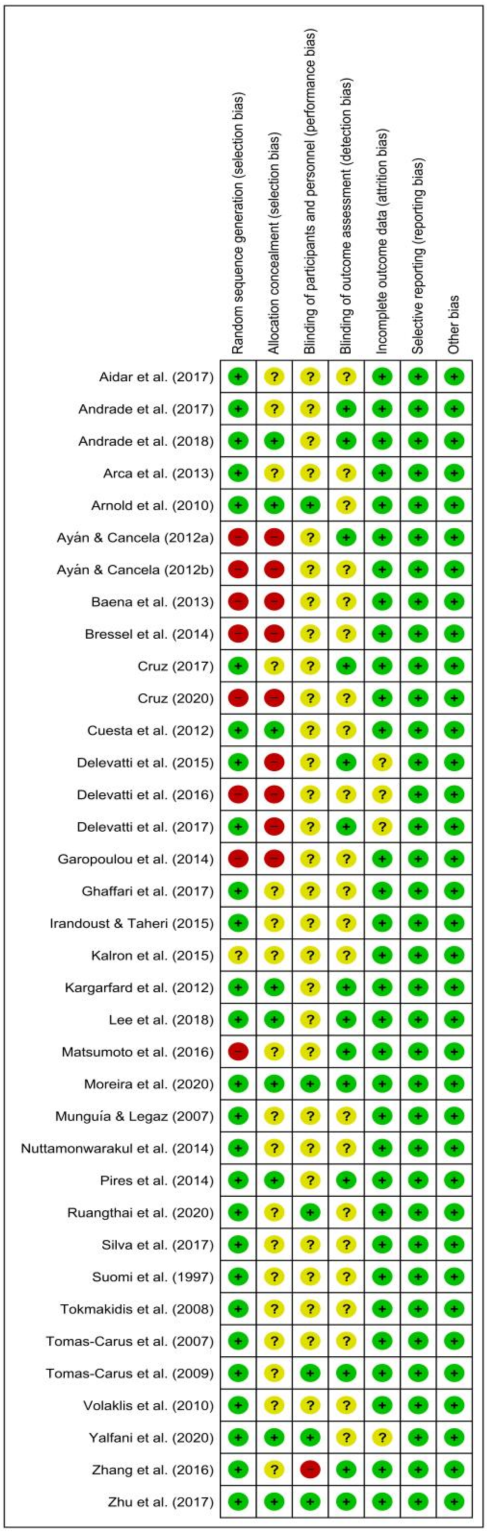


Figure 8. Risk-of-bias item presented as percentages across randomized studies for population with diseases.



	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Binding of participants and personnel (performance bias)	Binding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Aidar et al. (2017)	+	?	?	?	+	+	+
Andrade et al. (2017)	+	?	?	+	+	+	+
Andrade et al. (2018)	+	+	?	+	+	+	+
Arca et al. (2013)	+	?	?	?	+	+	+
Arnold et al. (2010)	+	+	+	?	+	+	+
Ayán & Cancela (2012a)	−	−	?	+	+	+	+
Ayán & Cancela (2012b)	−	−	?	?	+	+	+
Baena et al. (2013)	−	−	?	?	+	+	+
Bressel et al. (2014)	−	−	?	?	+	+	+
Cruz (2017)	+	?	?	+	+	+	+
Cruz (2020)	−	−	?	?	+	+	+
Cuesta et al. (2012)	+	+	?	?	+	+	+
Delevatti et al. (2015)	+	−	?	+	?	+	+
Delevatti et al. (2016)	−	−	?	?	?	+	+
Delevatti et al. (2017)	+	−	?	+	?	+	+
Garopoulou et al. (2014)	−	−	?	?	+	+	+
Ghaffari et al. (2017)	+	?	?	?	+	+	+
Irandoust & Taheri (2015)	+	?	?	?	+	+	+
Kalron et al. (2015)	?	?	?	?	+	+	+
Kargarfard et al. (2012)	+	+	?	+	+	+	+
Lee et al. (2018)	+	+	?	+	+	+	+
Matsumoto et al. (2016)	−	?	?	+	+	+	+
Moreira et al. (2020)	+	+	+	+	+	+	+
Munguía & Legaz (2007)	+	?	?	?	+	+	+
Nuttamonwarakul et al. (2014)	+	?	?	?	+	+	+
Pires et al. (2014)	+	+	?	+	+	+	+
Ruangthai et al. (2020)	+	?	+	?	+	+	+
Silva et al. (2017)	+	?	?	?	+	+	+
Suomi et al. (1997)	+	?	?	?	+	+	+
Tokmakidis et al. (2008)	+	?	?	?	+	+	+
Tomas-Carus et al. (2007)	+	?	?	?	+	+	+
Tomas-Carus et al. (2009)	+	?	+	+	+	+	+
Volaklis et al. (2010)	+	?	?	?	+	+	+
Yalfani et al. (2020)	+	+	+	?	?	+	+
Zhang et al. (2016)	+	?	−	+	+	+	+
Zhu et al. (2017)	+	+	+	+	+	+	+

Figure 9. Judgments about each risk-of-bias item for each randomized study for population with diseases. + indicates low risk, ? indicates unclear risk, – indicates high risk.

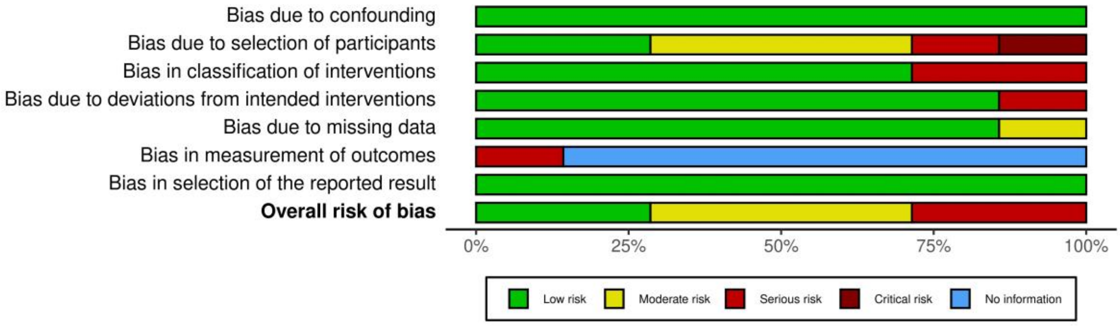
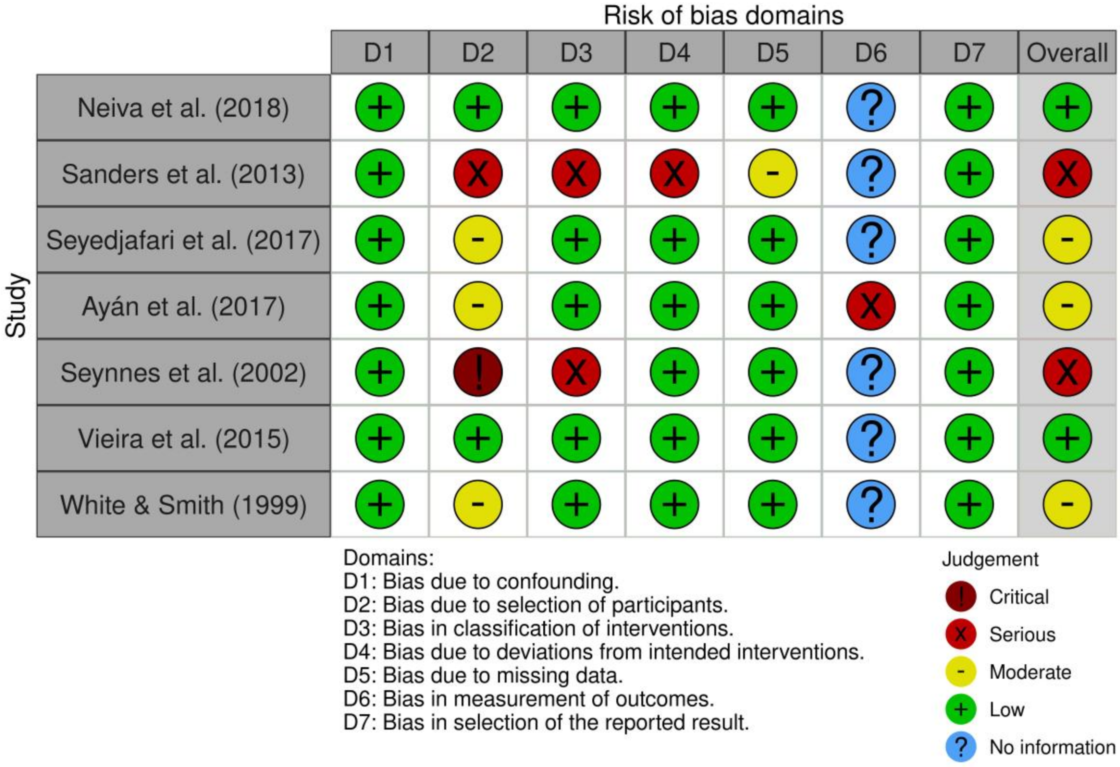


Figure 10. Risk-of-bias item presented as percentages across nonrandomized studies for healthy population.



Study	D1	D2	D3	D4	D5	D6	D7	Overall
Neiva et al. (2018)	+	+	+	+	+	?	+	+
Sanders et al. (2013)	+	X	X	X	-	?	+	X
Seyedjafari et al. (2017)	+	-	+	+	+	?	+	-
Ayán et al. (2017)	+	-	+	+	+	X	+	-
Seynnes et al. (2002)	+	!	X	+	+	?	+	X
Vieira et al. (2015)	+	+	+	+	+	?	+	+
White & Smith (1999)	+	-	+	+	+	?	+	-

Figure 11. Judgments about each risk-of-bias item for each nonrandomized study for healthy population. ! indicates critical risk, X indicates serious risk, - indicates moderate risk, + indicates low risk, ? indicates no information.

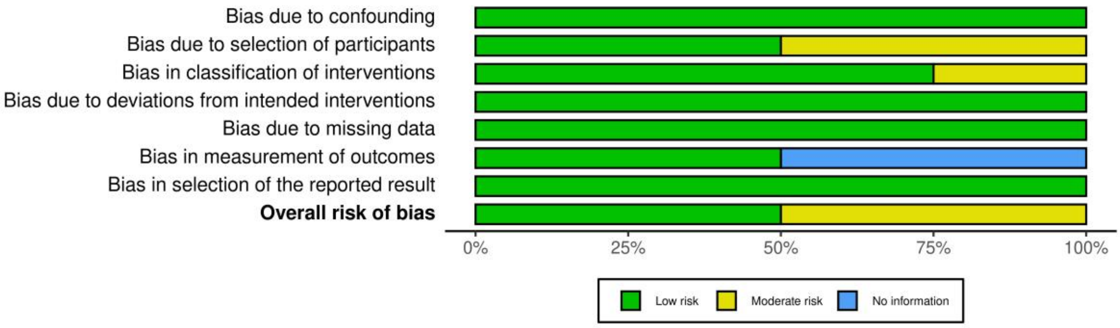
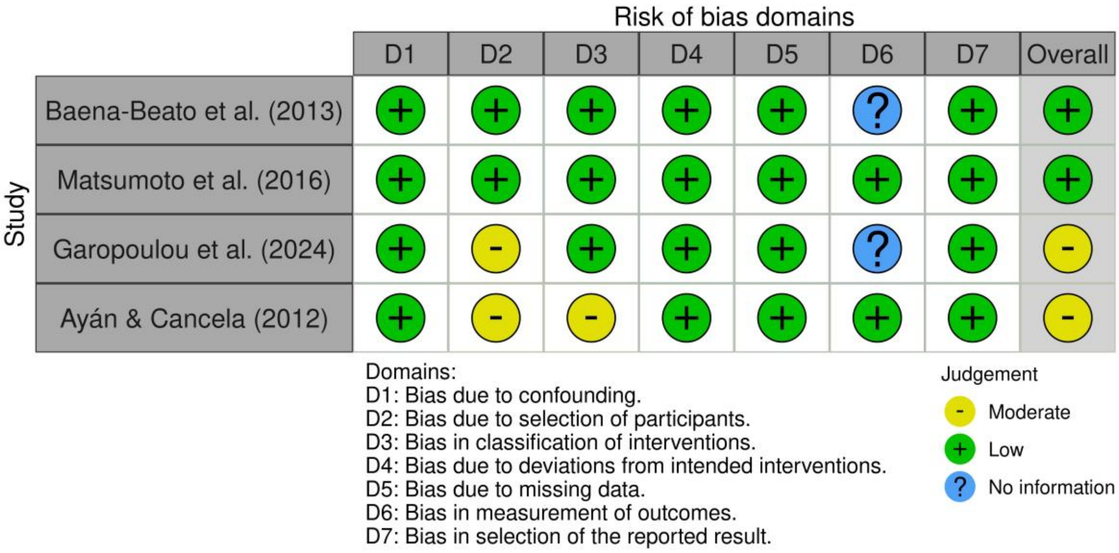


Figure 12. Risk-of-bias item presented as percentages across nonrandomized studies for population with diseases.



Risk of bias domains

Study	D1	D2	D3	D4	D5	D6	D7	Overall
Baena-Beato et al. (2013)	+	+	+	+	+	?	+	+
Matsumoto et al. (2016)	+	+	+	+	+	+	+	+
Garopoulou et al. (2024)	+	-	+	+	+	?	+	-
Ayán & Cancela (2012)	+	-	-	+	+	+	+	-

Domains:
D1: Bias due to confounding.
D2: Bias due to selection of participants.
D3: Bias in classification of interventions.
D4: Bias due to deviations from intended interventions.
D5: Bias due to missing data.
D6: Bias in measurement of outcomes.
D7: Bias in selection of the reported result.

Judgement
- Moderate
+ Low
? No information

Figure 13. Judgments about each risk-of-bias item for each nonrandomized study for population with diseases. ! indicates critical risk, X indicates serious risk, - indicates moderate risk, + indicates low risk, ? indicates no information.

Discussion

This review aimed to verify the changes in health and physical fitness parameters produced by WT in both healthy adults and adults with chronic diseases. In different populations, WT was shown to be significantly effective, improving several parameters related to physical fitness and health-related outcomes. Regarding healthy adults, there were significant enhancements in strength, balance and cardiorespiratory fitness. When analysing adults with chronic disease, WT was demonstrated to be beneficial for health and physical fitness, mainly in the QoL and balance, but also in strength, pain, and gait.

Healthy adults

Regarding healthy adults, the positive effects were mostly related to strength (Poyhonen et al., 2002; López et al., 2017; Reichert et al., 2016; Reichert et al., 2018; Robinson et al., 2004; Sanders et al., 2013; Seyedjafari et al., 2017; Tsourlou et al., 2006; Vale et al., 2020), cardiorespiratory fitness (Lambert et al., 2014; Reichert et al., 2016; Reichert et al., 2021; Sanders et al., 2013) and balance (López et al., 2017; Reichert et al., 2016; Seyedjafari et al., 2017; Tsourlou et al., 2006; Vale et al., 2020), being these variables the main responsible for the medium overall effect (SMD = -0.66). Nevertheless, contradictory results were found with respect to flexibility (Carral & Pérez, 2007; López et al., 2017; Miller et al., 2002; Moreira et al., 2017; Reichert et al., 2016; Tsourlou et al., 2006; Vale et al., 2020; Vieira et al., 2015) and BP (Lambert et al., 2014; Neiva et al., 2018; Reichert et al., 2016), and no significant changes were observed in anthropometrics (Neiva et al., 2018; Tsourlou et al., 2006). Most of the outcomes analyzed were shown to require at least 12 weeks of WT with 2-3 weekly sessions lasting between 46 and 65 min each.

Improvements in cardiorespiratory fitness were mainly promoted in studies with a duration of at least 12 weeks (Lambert et al., 2014; Reichert et al., 2018). Moreover, better results seem to exist after an aquatic program compared to LT (Lambert et al., 2014). This can be explained by the difference in fluid densities, for which air is nearly 800 times lower than water (Kumar et al., 2015; Sanders et al., 2013). Consequently, water offers more resistance to movement than air, thus requiring greater energy expenditure and putting a higher load on cardiac function, allowing cardiorespiratory levels to increase (Kumar et al., 2015). We should be aware that the intensity used in these programs was not fully reported/monitored, which could produce different results. For instance, in WT, interval training has been shown to be more effective in improving HR and oxygen consumption than continuous training (Vieira et al., 2015). These results seem to be enhanced when interval training is combined with the aid of additional loads, specifically floating vests, preventing contact of the feet with the bottom of the pool, removing the impact, and allowing higher physical demand and a reduced risk of injuries (Kanitz et al., 2015; Reichert et al., 2016).

There is a belief that WT is not the most reliable way to improve strength (Wertheimer et al., 2018). However, some recent studies found that WT focused on resistance training increased maximal dynamic strength (Reichert et al., 2018). These unclear results could be explained by the low intensity (undefined in most of the studies) or different water depths used. According to

Kanitz et al. (2015), the improvement in strength depends on the water depth, with shallow water being more propitious to produce better results than deep water. In deep water, the feet do not touch the bottom of the pool, which could reduce muscle stimulation, the maximum speed of movement, and the production of force. This type of resistance exercise can also influence strength. For example, plyometric training is commonly used in programs outside of the water and is associated with improvements in muscular strength and explosiveness (Jurado-Lavanant et al., 2015; Miller et al., 2002; Stemn & Jacobson, 2007). This training method was also effective at improving strength when performed in water for 8 weeks (Robinson et al., 2004). These results are interesting since they contradict the suggestions that the aquatic environment provides little strain on muscles and bones (Bento et al., 2015; Jurado-Lavanant et al., 2015). The velocity of the movement that is required by this training method could allow an increase in intensity, thus improving force production (Reichert et al., 2018). However, it is necessary to be careful about the excessive and inappropriate use of these exercises, as they can cause muscle injuries (Wertheimer et al., 2018). The main results suggested that plyometrics might be used to improve strength after 8 weeks of training, as long as used with caution.

The meaningful increases in balance could be due to the hydrostatic pressure and viscous force produced by the water during the exercises, allowing a different proprioceptive and sensory response in water compared to the land. This positively affects neuromuscular coordination, balance ability, and postural control (Oliveira et al., 2014; Seyedjafari et al., 2017). Moreover, the improvement in balance could be due to continuous muscle activation that is required to stabilize body position (Oliveira et al., 2014). By adding resistance equipment, it is possible to further potentiate the static and dynamic balance as a result of the simultaneous stimulation of the leg muscles and the muscles of support involved in spinal and pelvic movements (Moreira et al., 2017; Seyedjafari et al., 2017). Nevertheless, the depth at which the activity is performed influences balance acquisition. Bento et al. (2015) reported that it is possible to increase the levels of static and dynamic balance to a depth greater than 2 meters, but they were unable to develop static balance (only dynamic) with water at the level of the xiphoid process.

Adults with chronic disease

The literature regarding the effect of WT in participants with chronic diseases is mainly focused on musculoskeletal diseases, heart diseases, diabetes mellitus, multiple sclerosis, and Parkinson’s disease. Of these, the best results after performing aquatic programs were found in those who suffered from musculoskeletal diseases, diabetes, and multiple sclerosis. Nevertheless, the individuals with Parkinson's disease moderately improved the generality of health and physical fitness parameters. Regarding the outcomes with the greatest improvement in several studies were balance (Ayán & Cancela, 2012b; Bressel et al., 2014; Delevatti et al., 2015; Kalron et al., 2015; Lee et al., 2018; Moreira et al., 2020; Tomas-Carus et al., 2009), and QoL (Ayán & Cancela, 2012b; Baena-Beato et al., 2013; Delevatti et al., 2017; Garopoulou et al., 2014; Kalron et al., 2015; Matsumoto et al., 2016; Ruangthai et al., 2020; Tomas-Carus et al., 2009; Zhu et al., 2017), but also in strength (Baena-Beato et al., 2013; Moreira et al., 2020; Tomas-Carus et al., 2009; Volaklis et al., 2007), and pain (Baena-Beato et al., 2013; Bressel et al., 2014; Cruz, 2017; Cuesta-Vargas et al., 2012; Moreira et al., 2020; Pires et al., 2014; Yalfani et al., 2020), and although little studied, gait also improved significantly (Cruz, 2017; Kalron et al., 2015; Zhu et al., 2017). Some parameters were not affected by WT: anthropometry in individuals with fibromyalgia (Andrade et al., 2017), diabetes (Nuttamonwarakul et al., 2014) and hypertension (Arca et al., 2013; Ruangthai et al., 2020); the lipid profile in subjects with coronary artery disease (Irandoust & Taheri, 2015) and hypertension (Arca et al., 2013); cardiorespiratory fitness in people who suffered from a stroke (Lee et al., 2018; Matsumoto et al., 2016) and coronary artery disease (Tokmakidis et al., 2008; Volaklis et al., 2007); and flexibility in individuals with fibromyalgia (Tomas-Carus et al., 2007). Furthermore, in most of the chronic diseases analyzed, it was observed that the most suitable duration of WT to produce significant effects on the different outcomes was 8-16 weeks of training, 3 times per week for 45-65 min. The exceptions are in individuals with Parkinson's disease (2/5 sessions per week), and heart diseases (2-4 times per week).

Musculoskeletal Diseases

In musculoskeletal diseases, we analyzed studies that investigated the effects of WT on fibromyalgia and bone diseases. In general, major improvements were found in pain, cardiorespiratory fitness, flexibility, QoL and strength, with these variables providing a substantial contribution to the large overall effect (SMD = -1.11). Concerning individuals with fibromyalgia, we recognize the advantages of WT, essentially in balance (Tomas-Carus et al., 2009) and cardiorespiratory fitness (Tomas-Carus et al., 2007). These outcomes are relevant, considering that this disease is strongly associated with problems of balance and frequent falls (Latorre et al., 2013) due to sensory disorders and muscle weakness (Tomas-Carus et al., 2009). In line with these improvements, we also verified slight improvement in strength, especially among individuals using WT with an emphasis on aerobic and resistance training (Tomas-Carus et al., 2009). Although there are potential improvements in QoL (Tomas-Carus et al., 2009), only a few studies analyzed this variable, and more water training (≥ 12 weeks, three weeks, ≈ 60 min duration each session) was required to manifest strong effects. When the purpose of the training is to relieve successive pain, such as the typical symptoms of fibromyalgia, exercise/therapy should occur in water at temperatures between 30°C and 34°C (Irandoust & Taheri, 2015).

Regarding bone diseases, the studies investigated arthritis/osteoarthritis and low back pain. In these studies, the perception of pain (Baena-Beato et al., 2013; Bressel et al., 2014; Cuesta-Vargas et a., 2012; Moreira et al., 2020; Pires et al., 2014; Yalfani et al., 2020), balance (Bressel et al., 2014; Moreira et al., 2020), flexibility (Baena-Beato et al., 2013; Moreira et al., 2020) and strength (Baena-Beato et al., 2013; Moreira et al., 2020) showed better results, with some also significant effects in QoL (Baena-Beato et al., 2013), in anthropometry (Irandoust & Taheri, 2015), and in cardiorespiratory fitness (Baena-Beato et al., 2013). To observe these greater effects, 6-16 weeks of training, 2-3 times per week, are needed. In diseases such as low bone mineral density, osteoporosis, joint pain, and muscle weakness (Aboarrage Junior et al., 2018; Arnold & Faulkner, 2020; Pernambuco et al., 2013), the literature recognizes the need to generate an impact to increase the osteogenic effect through the tension and compression that the bone is subjected to when exposed to different loads (Aboarrage Junior et al., 2018). As previously noted, the properties of the aquatic environment, namely, fluctuation, reduced impact and led to the WT being classified as exercises with low osteogenic effects (Aboarrage Junior et al., 2018; Alkatan et al., 2016; Suomi & Lindauer, 1997). Despite this, one of the main purposes of research in most bone diseases is to attempt to lighten the pain caused by the respective diseases, as successfully attained in some investigations (Baena-Beato et al., 2013; Bressel et al., 2014; Cuesta-Vargas et a., 2012; Moreira et al., 2020; Pires et al., 2014; Yalfani et al., 2020). Thus, WT seems to be a safe method when the intention is to reduce the pain of these patients. It should be noted that although water exercise could be unfavorable in the direct increase in bone mineral density, some increases in muscle strength can help to strengthen the bone (Aboarrage Junior et al., 2018). However, for this to occur, it is necessary to perform exercises at high intensities, recruit type II muscle fibers, and stimulate the strengthening of bone tissue (Wing-Hoi et al., 2010). Moreover, WT also has positive effects on low back pain, probably because the exercise performed in water is propitious to aerobic training at higher intensities than would be possible on land (Baena-Beato et al., 2013).

Heart Diseases

The heart diseases assessed were coronary artery disease, hypertension, and stroke. In people with coronary artery disease, there were significant changes, essentially in strength (Volaklis et al., 2007) and anthropometry (Volaklis et al., 2007), after performing a WT. In the case of hypertension, there were no great changes, however the positive effects were mainly on QoL (Ruangthai et al., 2020), despite them being ineffective in anthropometry (Arca et al., 2013; Ruangthai et al., 2020) and lipid profile (Arca et al., 2013; Ruangthai et al., 2020). There was a lack of studies on BP, and this is considered the most accurate predictor of future coronary artery disease in individuals over 50 years of age (Conners et al., 2018; Lloyd-Jones et al., 2000; Silva et al., 2009; Tanaka et al., 1997; Zanchetti & Waeber, 2006). Concerning individuals with stroke, these developments in QoL (Matsumoto et al., 2016) with water and exercise are essentially due to the viscosity and drag forces that reduce the spastic response of the muscle and pain (Matsumoto et al., 2016). Ultimately, despite the large effects on some indicators (QoL), and the small overall effect (SMD = -0.36) obtained by patients with heart diseases, the studies examined herein did not fully elucidate the impact of WT on heart diseases.

Diabetes Mellitus

The programs performed in an aquatic context proved to be indicated for diabetes, particularly when the aim was to improve balance (Delevatti et al., 2015) and QoL (Delevatti et al., 2017). Furthermore, BP (Delevatti et al., 2015) and lipid profile (Delevatti et al., 2016), also revealed favorable results after the practice of these activities, highlighting the improvement in glucose levels (Delevatti et al., 2016). In all of these outcomes, 12 weeks of WT, with 3 lessons weekly, for 45-50 min each lesson, were required to produce significant effects in people with diabetes. Nevertheless, there is a lack of studies with a program duration beyond 12 weeks. Additionally, further studies are needed in these individuals to analyse body composition, cholesterol and triglyceride responses. A possible improvement in these parameters, together with the results obtained in glucose (with nutritional control), can decrease the risk of developing heart problems (Conners et al., 2018; Nuttamonwarakul et al., 2014).

Multiple Sclerosis

Individuals with multiple sclerosis participating in WT had considerable improvements in their QoL (Garopoulou et al., 2014; Kargarfard et al., 2012) and balance (Kalron et al., 2015), and slight increases in gait (Kalron et al., 2015) and fatigue (Kargarfard et al., 2012). The improvement in gait after a short WT of 3 weeks should be highlighted (Kalron et al., 2015); this is perhaps due to the fact that water enables weight to be reduced and resistance to be increased during exercise due to buoyancy (Garopoulou et al., 2014). These results are even more important considering that patients with multiple sclerosis lose the capacity to walk over the years (Ghaffari et al., 2017). Moreover, WT performed systematically was shown to improve the QoL of individuals with multiple sclerosis (Garopoulou et al., 2014; Kargarfard et al., 2012) maybe due to gains in walking ability and decreased fatigue (Garopoulou et al., 2014; Kargarfard et al., 2012; Kargarfard et al., 2017). Training in water 3 times/week for 8 weeks seems to be sufficient for substantial improvements in these outcomes, regardless of session duration. Therefore, it is necessary to consider the training method to be applied, as aerobic training seems to be more effective than resistance training, presumably due to the improvement of cardiovascular capacity resulting from the superior capacity to produce work in the aquatic environment (Garopoulou et al., 2014).

Parkinson’s disease

Interestingly, Parkinson's disease has been recently studied regarding the effects of WT. In these subjects, pain (Cruz, 2017), QoL (Ayán & Cancela, 2012b; Zhu et al., 2017), cardiorespiratory fitness (Ayán & Cancela, 2012a), and gait (Zhu et al., 2017) levels were mainly improved, and in the background, there were also moderate changes in balance (Ayán & Cancela, 2012b), with a medium overall effect obtained essentially by these indicators. The hydrostatic pressure, turbulence, and buoyancy allow more demanding work in postural control, mobility and stimulation at a higher level in Parkinson's disease patients (Zhu et al., 2017). Moreover, water temperature also plays a key role because warm water increases body temperature, dilates blood vessels, relaxes muscles, reduces muscle stiffness, and optimizes balance (Zhu et al., 2017). This is important because the QoL among these patients increases mainly due to the development of balance and the consequent decrease in the number of falls (Ayán & Cancela, 2012b), improvements in the mental and emotional state through social interaction in group exercise (Ayán & Cancela, 2012a; Ayán & Cancela, 2012b) and pain reduction (Cruz, 2017). Only 6 weeks (2/5 lessons per week) of WT was sufficient to significantly improve most outcomes among people with Parkinson's disease.

In conclusion, the current review suggested that WT is reliable for obtaining improvements in the health and physical fitness of adults with and without chronic diseases. In healthy individuals, WT mainly improves strength, cardiorespiratory fitness and balance. Although specific adaptations exist according to each disease, it can be reported that water-based programs mainly improve the balance, QoL, strength, pain and gait in adults with chronic diseases.

Perspective

Worldwide, the participation in physical activity training programs performed in-water has increased, mainly because of the specific properties of the water. Research suggests that exercise, and specifically WT, could be used as a complement to medical treatment for health-related issues or to maintain/improve physical fitness and QoL (Pedersen & Saltin, 2015). The WT is mainly recommended for people with specific diseases, but little was known about the ideal practices to be performed. We highlighted the effects on balance, cardiorespiratory fitness and strength in healthy adults, whereas balance, QoL, strength, pain and gait were improved in individuals with chronic diseases. Beneficial effects in healthy adults seem to be consistent after 12 weeks of training, with 2-3 sessions per week of 46-65 min. Although further research is needed to define the optimal dose of exercise in some diseases, in general, benefits in physical fitness and/or other health-related measures were observed after 8-16 weeks of WT. Future studies should better understand the effect of WT intensity, one of the main factors of exercise load. Additionally, more studies are needed on the effect of WT in individuals with specific diseases, for instance, those with heart disease.

Chapter 3. Experimental Studies

Study 2. Effects of 12-week moderate-intensity vs high-intensity water-aerobic training on physical fitness, cardiovascular health, and well-being in adults and older adults: A pragmatic randomized controlled trial

Abstract

The current study aimed to compare the effects of 12 weeks of moderate versus high-intensity water aerobics on muscle strength, body composition, lipid profile, blood pressure, and quality of life (QoL) in both adults and older adults. Twenty-one women (65.19 ± 9.37 years) were randomly allocated to moderate (MIG; n=11) or high-intensity groups (HIG; n=10). Both groups attended 45-minute sessions twice a week for 12 weeks. Assessments at baseline and post-training included muscle endurance, explosive strength, body mass, body mass index, fat mass, fat-free mass, triglycerides, total cholesterol, blood pressure, resting heart rate, general QoL, and general health, and the physical, psychological, social relationships, and environmental domains of QoL. HIG experienced greater reductions in total cholesterol ($\eta_p^2 = 0.28$) and fat mass ($\eta_p^2 = 0.35$), and an increase in fat-free mass ($\eta_p^2 = 0.35$), compared to the MIG. The HIG also showed greater improvements in triglycerides ($\eta_p^2 = 0.24$) and physical QoL ($\eta_p^2 = 0.19$) than MIG. No significant group x time interactions were found in the other variables. Nevertheless, muscular endurance and psychological QoL were improved in both groups ($p < 0.05$, ES ≥ 0.57). The HIG was the only group to experience a reduction in diastolic BP ($p = 0.04$, ES = -0.71), while the MIG showed no significant change. Explosive strength did not change in either group. The study suggests that high-intensity water aerobics provide additional benefits over moderate intensity for body composition, blood lipids, diastolic BP, and physical QoL in adults and older adults. However, both intensities effectively improved muscular endurance and psychological QoL. Future studies should include a larger number of participants and groups (e.g., control group), longer interventions, and controlled dietary intake. Nonetheless, the current results demonstrate that exercise intensity is an important variable for optimal water aerobics outcomes.

Keywords: Aquatic exercise, intensity, physical fitness, health-related, quality of life

Introduction

Health and sports professionals have increasingly recommended engaging in aquatic exercise (Neiva et al., 2018; Raffaelli et al., 2016). Among aquatic activities, water aerobics has been particularly recognized by the scientific community for its ability to improve cardiorespiratory capacity (Broman et al., 2006; López et al., 2017; Nikolai et al., 2009), muscle strength (López et al., 2017; Moreira et al., 2018; Neiva et al., 2018; Tsourlou et al., 2006) and anthropometric parameters (Kantyka et al., 2015; Neiva et al., 2018; Tsourlou et al., 2006). The specific properties of water, such as buoyancy, drag forces, and lack of hypogravity (Neiva et al., 2018; Pöyhönen et al., 2002) contribute to the improvements in health and physical fitness that make aquatic activities highly recommended for older adults and individuals recovering from injury (Benelli et al., 2004; Colado et al., 2009). Recent evidence suggests that aquatic programs can promote improvements in balance, quality of life (QoL), strength, pain, and gait in individuals with chronic diseases (e.g., fibromyalgia, bone diseases, some heart diseases, diabetes, multiple sclerosis, and Parkinson's), although adaptations are specific to each disease (Faíl et al., 2022). Furthermore, aquatic exercise has also been shown to improve strength, balance, and cardiorespiratory fitness in healthy populations (Faíl et al., 2022).

Most studies conducted on adults and older adults have primarily focused on the effects of water aerobics on muscle strength and body composition (Alves et al., 2004; Jasiński et al., 2015; Kantyka et al., 2015; Moreira et al., 2018; Neiva et al., 2018; López et al., 2017). This interest is likely due to the increased risk of sarcopenia among individuals aged 50 to 80 years (Beaudart et al., 2017; Buch et al., 2016), as well as the fact that water aerobics is an activity widely practiced by people with obesity and/or locomotor problems (Raffaelli et al., 2016). However, despite its popularity, there is a lack of scientific evidence supporting its effects on lipid profile, blood pressure (BP), and QoL (Garrido et al., 2016; Kantyka et al., 2015; Neiva et al., 2018). Water aerobics classes can play a crucial role in improving various health parameters, as they are closely linked to cardiovascular diseases (Lewington et al., 2002; Magalhães et al., 2017). Furthermore, as individuals age, their QoL tends to decline (Sampaio & Ito, 2013), making water aerobics classes all the more valuable.

While the results of water aerobics programs are often positive, the impact of various training variables has been inadequately studied. In terms of training volume, i.e., the time dedicated to water aerobics sessions, research suggests that durations between 45 and 60 minutes per class, conducted 2-3 times per week, tend to yield favorable results, particularly for training periods lasting 12 to 24 weeks (Alves et al., 2004; Colado et al., 2009; Kantyka et al., 2015; Moreira et al., 2018; Neiva et al., 2018; Takeshima et al., 2002; Tsourlou et al., 2006). However, many programs fail to monitor and/or report crucial information about exercise intensity and its effects (Faíl et al., 2022). The intensity at which an exercise is performed is a vital aspect of designing and controlling any exercise program (Graef et al., 2006). Additionally, aquatic exercise requires higher effort intensity but elicits a lower perception of effort compared to similar land-based activities (Jasiński et al., 2015). This can facilitate performing aquatic exercise at high intensities, although limited information exists on its effects in water aerobics. Furthermore, no studies have analyzed the effects of performing water aerobics at moderate versus high intensities.

To comprehend the optimal intensity of water aerobics for attaining optimal health and fitness enhancements, it is essential to assess the effects of water aerobics based on the intensity utilized. Given that water aerobics is widely practiced by adults and older individuals, it is crucial to investigate the ideal intensity for this particular population. To the best of our knowledge, no study has examined this in adults and older adults. For this reason, we aimed to analyse the impact of 12 weeks of moderate and high-intensity water aerobics on muscle strength, body composition, lipid profile, BP, and QoL in adults and older adults. We hypothesized that all variables would improve following training, regardless of intensity. Furthermore, we hypothesized that there would be greater improvements across all parameters with high-intensity training compared to moderate intensity.

Material and Methods

Study design

This was a pragmatic randomized controlled trial (pRCT) (Registration: NCT06509217), in adults and older adults, with balanced randomization (1:1) to each group (moderate or high intensity), conducted in Portugal. This was a double-blinded study to analyse the effects of 12 weeks of moderate and high-intensity water aerobics on muscle strength, body composition, lipid profile, BP, and QoL in adults and older adults.

Participants

The participants were recruited from the same residential area and municipal swimming pool in Tramagal, Abrantes, Portugal. The participants from various classes received both oral and written instructions regarding the study's objectives. Those who agreed to take part in the study signed the informed consent form and were randomly assigned to each group. Although no dietary intake was assessed, the participants were asked not to alter their eating habits. The study protocol was approved by the Ethics Committee of the University of Beira Interior, Portugal (CE-UBI-Pj-2019-051). To be eligible for the study, individuals had to be 18 years old or older and attend two classes per week. The following criteria were used to exclude participants: taking part in another physical exercise program, being recently hospitalized, having severe motor or cognitive problems, or having any medical restrictions on physical exercise. While being a man was not considered an exclusion criterion, only women completed the study.

Intervention

Participants in the study were randomly assigned to either the moderate-intensity group (MIG) or the high-intensity group (HIG). The water aerobics classes for both groups lasted approximately 45 minutes and were held twice a week for a period of 12 weeks. The MIG classes were conducted at moderate intensities, ranging from 60% to 70% of the maximum heart rate (HR_{max}) predicted by age (HR_{max} = 207 - 0.7 x age) (Gellish et al., 2007). Following the calculation of the HR_{max}, we proceeded to assess the resting HR of all participants in two conditions: out of the water and in the water. Subsequently, the resting HR recorded in the water was subtracted from the resting HR measured out of the water. Finally, this resultant difference was deducted from the HR_{max} value derived using the formula established by Gellish et al. (2007). Each session comprised a 5-minute warm-up (88.14 ± 7.98 bpm), a 35-minute aerobic workout (113.70 ± 6.23 bpm), and a 5-minute cool-down (93.45 ± 7.86 bpm). The HIG classes were similar to the MIG classes but were conducted at high intensities, ranging from 80% to 90% of the HR_{max} predicted by age. The HIG recorded the following HR values: warm-up (96.35 ± 9.35 bpm), workout (124.73 ± 7.37 bpm), and cool-down (101.95 ± 7.38 bpm). In both groups, the intensity of the classes was manipulated through the musical cadence (Barbosa et al., 2010; Costa et al., 2011), and the HR was monitored once every two weeks for all participants. The warm-up and cool-down included exercises, such as walking forward and backward, performing lateral movements, and stretching all major muscle groups. The workout comprised a variety of exercises, including runs, steps sideways, swings, kicks, jumps, squats, hip flexion, extension, abduction, and adduction, both with and without equipment (e.g., dumbbells, water noodles, etc.). Table 1 provides the main exercises of routine workouts of the water aerobics programs (Alberton et al., 2013; Pinto et al., 2011; Raffaelli et al., 2010). The water aerobics classes were held at a temperature of about 29.0ºC and a depth of 1.50 m. The instructor of the water aerobics classes was informed about the study, and no external pressure was exerted to influence the instructor's activities. The instructor conducted exercises typically performed before the study began but with different intensities in each group.

Table 1. The main exercises performed in the workout routine of the Moderate-Intensity Group and High-Intensity Group through the 12 weeks.

Workout	Duration	Exercises	Brief description
Warm-up	5	Walking forward and backward, performing lateral movements, stretching all major muscle groups	
Main training program	35	Stationary running and walking	Right hip and knee flexion to 90°, followed by its extension *#
		Frontal kicks	Right hip flexes to 45°, followed by the knee extension and the ankle plantar flexing. Then, the right hip extends *#
		Alternate forward kicks	Simultaneously with the forward leg kick, the opposite arm is pushed out sideways and vice versa. The kicking foot must be raised to hip height.
		Alternate sideways kicks	At the same time as the leg kicking sideways, the opposite arm is pushed forward, and the other arm is pushed out sideways. The kicking foot should be raised to hip height.
		Squat jumps	Knee flexion of 90°, torso straight, and feet shoulder-width apart. When jumping, legs should be fully extended. Upon landing, both feet should come together in an upright position with fully extended knees #
		Jumping jacks	In the first jump, abduction of both arms and legs at the same time. Then, in the second jump, adduction of the arms and legs to the initial position
		Cross country skiing	In the first jump, abduction of both arms and legs at the same time. Then, in the second jump, adduction of the arms and legs to the initial position
Cool down	5	Walking forward and backward, performing lateral movements, stretching all major muscle groups	

* Alternating with the left upper/lower limb, # simultaneously performing movements with the upper limbs

Outcome measures

The primary objectives of this study were to evaluate changes in muscle strength, body composition, lipid profile, and BP, with the secondary objectives being focused on QoL. To achieve this, the variables were assessed in the week before the start of the program (Pre) and in the week following its conclusion (Post). Assessments were conducted by the same team of experienced evaluators in a room suitable for evaluations, located within the municipal swimming pool facility. The two assessment days were separated by a 72-hour interval. On the first day, body composition, BP, and explosive strength were evaluated, while on the second day, 72 hours later, lipid profile, muscle endurance, and QoL were assessed. The order of assessments was maintained both during the Pre- and Post-evaluations. To ensure the best possible results, all participants were verbally encouraged to perform to the best of their abilities on all assessments.

Muscle strength

The explosive strength of the lower and upper limbs was assessed using the countermovement jump (CMJ) and medicine ball throw (MBT), respectively. For the CMJ, participants commenced the test on an Optojump platform (Optojump, Microgate, Bolzano, Italy) with feet positioned shoulder-width apart and hands resting on the waist. Three jumps with countermovement were performed, with participants instructed to jump as high as possible, with two minutes of rest between repetitions (Ramírez-Campillo et al., 2017). The CMJ demonstrated an average intraclass correlation coefficient (ICC) of 0.98 (95% CI: 0.96-0.99) and a coefficient of variation (CV) of 5.84%.

In the 3-kilogram MBT, participants were instructed to sit in a chair against the wall, resting their backs on the chair and supporting their feet on the floor. Each participant was then encouraged to throw the 3-kilogram medicine ball (Vinex model VMB-003R, Bhalla International, Delhi, India) as far as possible. To obtain the values, a tape measure was used. Each individual performed three throws, with a three-minute rest between each attempt (Harris et al., 2011). For both CMJ and MBT, the mean values were considered. The mean ICC for MBT performance was 0.96 (95% CI: 0.91-0.98), and the CV values were 1.67%.

The chair stand test (CST) and arm curl test were performed to assess the lower and upper limb endurance strength, respectively (Rikli & Jones, 1999). The CST entailed the participant sitting in the center of the chair with a straight back and feet shoulder-width apart and in full contact with the floor. The upper limbs were crossed at the wrist level and positioned against the chest. Upon receiving the starting signal, the participant rose to maximum extension and returned to the initial sitting position, striving to complete the maximum number of repetitions within a 30-second time frame.

In the arm curl test, the participant was seated in a chair with the back straight and fully leaning against the chair, with their feet flat on the floor. A 2 kg dumbbell was held in their dominant hand, and the test commenced with the forearm in a lower position, near the chair, perpendicular to the floor. Upon receiving the start signal, the participant performed a complete flexion of the forearm and then returned to the initial position of forearm extension. The evaluator encouraged the participant to perform as many repetitions as possible within a time limit of 30 seconds, counting each correct flexion performed (Rikli & Jones, 1999).

Body composition

The body composition parameters evaluated were body mass, body mass index (BMI), fat mass percentage (FM), and fat-free mass. The BMI was calculated by dividing the body mass value by the height squared. For this, each participant's height was measured using a precision stadiometer with a scale of 0.001 m (Seca 213, Hamburg, Germany). A bioimpedance balance was used to obtain body mass, body fat, and fat-free mass (Tanita, BC418 MA, Tokyo, Japan). For the correct extraction of these tests, participants were barefoot and dressed in as little clothing as possible (Marfell-Jones et al., 2012).

Lipid profile

Using lancets and specific strips, blood samples were collected from the participant's fingertip to assess triglycerides (TG) and total cholesterol (TC) (Accutrend Plus, La Roche, Germany). Blood samples were collected before exercise (after a 15-minute rest period) and at least 2 hours after the last meal. The assessment was carried out in the morning and the recommended meal, when taken, was recommended to be light. Each participant was advised to repeat the same meal and time procedures in both evaluations (pre- and post). The 2-hour fasting period was selected to balance the need for accurate lipid profile measurements with the practical considerations of participants' comfort and study logistics, particularly for older adults. While extended fasting periods (typically 8 hours) are standard in some clinical lipid assessments, research suggests that shorter fasting periods (2 to 4 hours) provide reliable data and are clinically relevant for assessing cardiovascular risk (Langsted & Nordestgaard, 2019; Nordestgaard et al., 2016; Ridker, 2008). We focused on observing changes in lipid profiles over time rather than establishing absolute baseline levels. Therefore, we considered a 2-hour fasting period appropriate. Shorter fasting periods improve participant compliance and comfort, especially in older adults, and minimize disruptions to their daily routine. This pragmatic approach is aligned with our study design and ensures reliable lipid measurements while maintaining high participant engagement.

Blood pressure measurements

BP was assessed using an automatic BP monitor (OMRON M4-1, Hoofddorp, Netherlands) after the participant was seated and resting for at least 20 minutes (American College of Sports Medicine, 2013). This test assessed systolic BP, diastolic BP, and heart rate (HR) at rest.

Quality of life

The WHOQOL-BREF (Portuguese version) questionnaire with 26 items was used to assess the participants' QoL (Serra et al., 2006). Of the 26 items, 2 are related to the general QoL and general health, and the remaining 24 items assess the perception of QoL in 4 domains: physical, psychological, social relationships, and environment. Following the scoring guidelines, the domain scores were transformed into a linear scale between 0 and 100 (Serra et al., 2006). The higher the final score, the higher the participant's QoL in each domain.

Sample size

An a priori power analysis was conducted using G*Power (v3.1.9.8, University of Kiel, Germany) (Kang et al., 2021) for sample size estimation and considering data from Neiva et al. (2018). The effect size was determined as medium, using Cohen (1988) criteria (converted to an effect size f of 0.31), and the correlation among repeated measurements to be more than 0.60. With a significance criterion of $\alpha = 0.05$ and power = 0.80, the minimum sample size needed for each group with this effect size is n = 10 (ratio 1:1), considering a 2-tailed analysis of variance with repeated measurements (two groups, pre-and post-test assessments). To allow for potential dropouts (considering the drop-out rate of 20%) we decided to select at least 4 participants to the sample before starting. The obtained final sample size for analysis of n = 21 (10 in the HIG and 11 in the MIG) is more than adequate to test the study hypothesis.

Randomization

The study design was a double-blind pRCT with participants being blinded to allocation to each experimental group. The study participants were allocated using a simple randomization method. A computer-generated list of random numbers was used to assign the participants to two study groups in a 1:1 ratio. Each number corresponded to a sealed opaque envelope containing details about the study group, ensuring that the randomization procedure was concealed. The sequential numbers remained undisclosed until the interventions were assigned. The randomization was conducted by three authors, with the researcher responsible for assigning participants to specific groups not informed in advance about the treatment regimen allocated to each participant. Due to the nature of this study, the main researcher and instructor, who were involved in both the testing and training at different intensities, were unable to be blinded. However, the research team involved in the evaluation (pre and post-test assessments) were also blinded.

Statistical analysis

We used the Statistical Package for Social Sciences (IBM SPSS Statistics for Windows, version 28.0, IBM Corp., Armonk, NY, USA) to perform the statistical analysis. Standard statistical procedures were selected to determine means, standard deviations, and 95% confidence limits. To test normality, the Shapiro-Wilks test ($n < 30$) was used, followed by the Levene test to confirm the homogeneity of variances. The reliability of measurements was assessed using ICC and CV across the three attempts. The ICC, calculated using a bidirectional mixed random effects model with absolute agreement, evaluates the consistency of the measurements, while the CV provides an additional measure of reliability. To compare pre-training variables between groups, the independent sample t-test was used, allowing to determine any significant differences at baseline between groups. A two-way mixed design analysis of variance (ANOVA) with one factor with repeated measures (pre-test and post-test) was used to examine how different interventions affect outcomes over time, assessing both the within-subject effects (changes over time) and between-subject effects (differences between groups). To further explore changes within each group from pre-test to post-test, paired samples t-tests were performed. This test was chosen because it accounts for the paired nature of pre- and post-intervention data within the same participants, allowing us to directly assess whether the intervention produced significant improvements in the measured outcomes. Additionally, the measurements met the assumptions of the test, ensuring its suitability and robustness for detecting significant changes within each group. We also calculated the effect size to estimate the variance between groups, using the partial eta squared (η_p^2) and Cohen's *dz* (ES) was calculated for within-subject comparisons (Cohen, 1988; Lakens, 2013). ES values were considered small (0.20-0.49), medium (0.50-0.79), and large (≥ 0.80), and the ηp2 values were classified as small (0.01-0.08), moderate (0.09-0.24) and large (≥ 0.25). A 2-sided p-value ≤ 0.05 was considered statistically significant.

Results

The recruitment took place in September 2022 and the follow-up occurred between October and December 2022. A total of 29 individuals were assessed for eligibility. Of these, 3 refused to participate in the study, and 2 did not meet the inclusion criteria. Twenty-two women and two men were considered eligible and were enrolled in the study. Of these, 12 were randomly allocated to the MIG and 12 to the HIG. However, 1 participant of the HIG lost to follow-up after completing the Pre-test due to being hospitalized by illness, while 2 other people, one from each group discontinued intervention due to injury. Thus, 21 women completed the study and were used in the analysis, with 10 included in the HIG and 11 in the MIG. Figure 1 shows the participant flow diagram throughout the study.

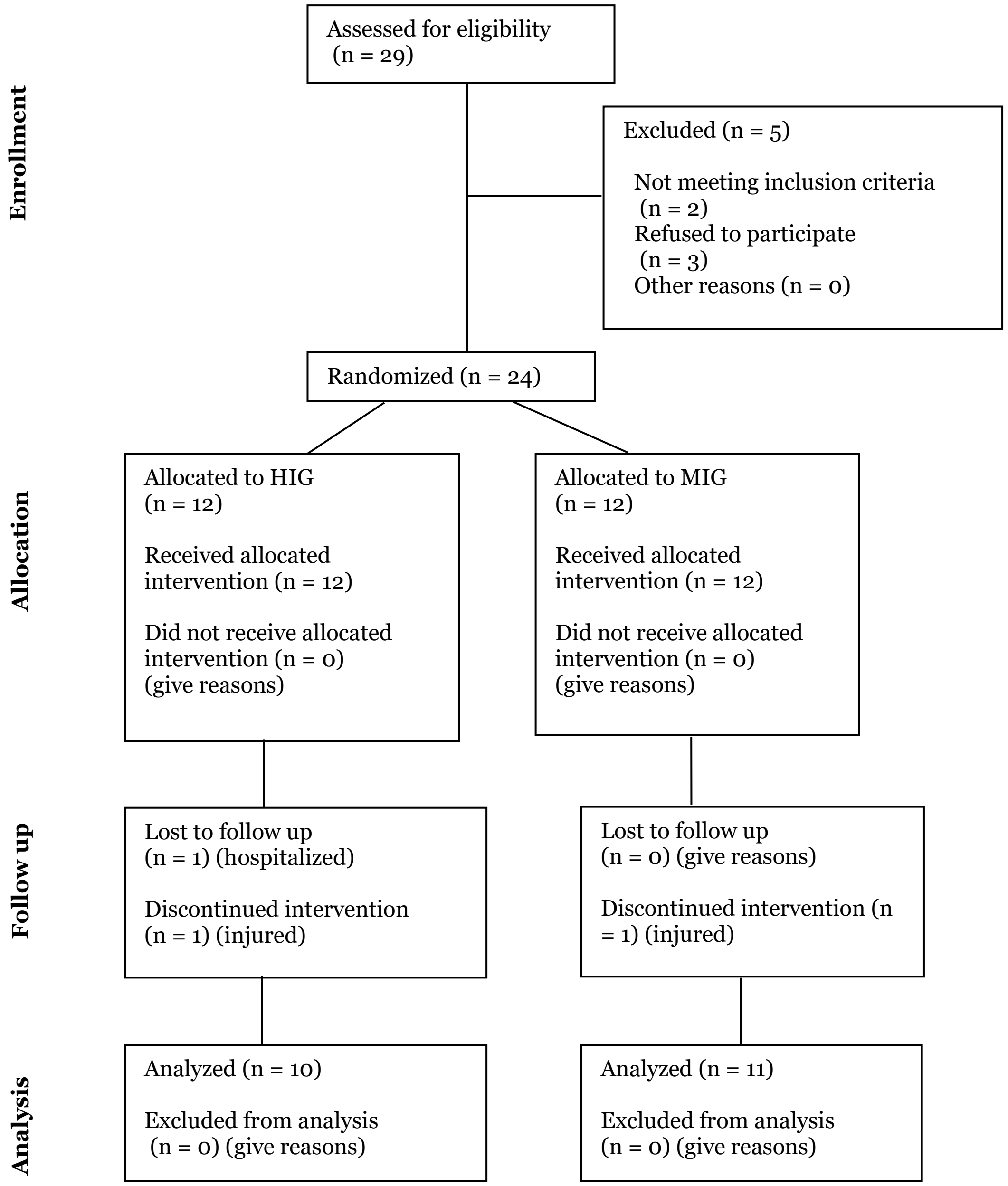


Figure 1. Flow diagram of the progress in a pragmatic randomized controlled trial to assess the effect of 12 weeks of moderate and high-intensity water aerobics on muscle strength, body composition, lipid profile, blood pressure, and quality of life in adults and older adults.

Table 2 lists the characteristics of the study participants. There were no significant between-group differences existed at baseline for any of the measures (all $p > 0.05$).

Table 2. Characteristics of the study participants of the MIG and HIG in baseline (mean ± SD).

Variable	MIG (n = 11)	HIG (n = 10)
Age (years)	63.18 ± 8.64	67.40 ± 10.09
Heigh (m)	1.58 ± 0.07	1.56 ± 0.06
Body mass (kg)	69.65 ± 10.44	75.94 ± 17.66
BMI (kg/m²)	28.16 ± 4.76	31.39 ± 7.63
Fat mass (%)	38.99 ± 5.68	41.53 ± 6.34
Fat-free mass (kg)	39.81 ± 3.15	41.30 ± 5.21

BMI Body Mass Index, *HIG* High Intensity Group, *MIG* Moderate Intensity Group, *SD* Standard Deviation

Primary outcomes

Table 3 displays the variables evaluated before and after training in the MIG and HIG groups. Concerning the muscle strength outcomes, no significant group x time interactions were identified for lower and upper body explosive strength assessed through CMJ (F = 0.32, p = 0.58, η_p^2 = 0.02) and MBT (F = 0.42, p = 0.53, η_p^2 = 0.02), as well as for lower and upper body muscular endurance measured using CST (F = 0.91, p = 0.35, η_p^2 = 0.05) and arm curl test (F = 0.50, p = 0.49, η_p^2 = 0.03). However, a significant time effect was observed for upper and lower muscular endurance in both groups, as their performance improved on the chair stand and arm curl tests. It is worth noting that no main effects were observed for upper and lower explosive strength.

Significant group x time interactions with large effect sizes were observed for FM (F = 10.36, p = 0.01, η_p^2 = 0.35) and fat-free mass (F = 9.99, p = 0.01, η_p^2 = 0.35), favoring the HIG. Consequently, a significant time effect was verified in these variables, with FM decreased, and fat-free mass increased in the HIG, while the opposite occurred in MIG. In contrast, no interactions or main effects were found for body mass (F = 0.03, p = 0.88, $\eta_p^2 \leq 0.01$) and BMI ($F \leq 0.01$, p = 0.98, $\eta_p^2 \leq 0.01$).

The lipid profile exhibited significant group x time interactions with large effects for TC (F = 7.38, p = 0.01, η_p^2 = 0.28) and moderate effects for TG (F = 6.03, p = 0.02, η_p^2 = 0.24), with the HIG showing greater improvements. A significant group effect was also found in TC and TG, reducing with the HIG, while no main effects existed in the MIG. Additionally, no interactions existed for diastolic BP (F = 0.48, p = 0.50, η_p^2 = 0.03), but a significant group effect was observed, improving in the HIG, without main effects on MIG. No interactions or main effects were verified for systolic BP (F = 0.23, p = 0.64, η_p^2 = 0.01), and resting HR (F = 0.75, p = 0.40, η_p^2 = 0.04).

The results indicate that the HIG exhibited greater effects in comparison to the MIG. The CST demonstrated positive large effects in the HIG (ES = 0.92 [mean value]), while the arm curl (ES = 0.75), fat-free mass (ES = 0.75), FM (ES = -0.69), TC (ES = -0.62), TG (ES = -0.62), and diastolic BP (ES = -0.71) displayed medium effects. In contrast, the MIG showed medium negative changes in fat-free mass (ES = -0.57) and FM (ES = 0.66). As depicted in Figure 2, the mean ES values and 95% CI confirm these findings.

Table 3. Muscle strength, anthropometric, lipid profile, blood pressure, and quality of life values of the Moderate Intensity Group and High Intensity Group in Pre and Post-training.

	Moderate Intensity Group (MIG) (n = 11)				**High Intensity Group (HIG) (n = 10)**			
	Pre	**Post**	**Change (± 95% CI)**	**p value**	**Pre**	**Post**	**Change (± 95% CI)**	**p value**
Strength								
CMJ [cm]	6.56 ± 3.49	7.22 ± 3.42	0.66 (± 0.98)	0.16	5.34 ± 3.57	5.67 ± 3.53	0.34 (± 0.79)	0.36
MBT [m]	2.29 ± 0.32	2.34 0 ± 0.27	0.05 (± 0.12)	0.35	2.12 ± 0.42	2.24 ± 0.60	0.12 (± 0.22)	0.24
CST [reps]	14.00 ± 2.93	15.55 ± 3.88	1.55 (± 1.33)	0.03*	15.80 ± 5.94	18.30 ± 5.96	2.50 (± 1.85)	0.01*
Arm Curl [reps]	19.18 ± 2.99	21.09 ± 4.23	1.91 (± 1.82)	0.04*	22.10 ± 7.46	25.1 ± 5.96	3.00 (± 2.74)	0.04*
Anthropometric								
Body Mass [kg]	69.65 ± 10.44	69.78 ± 10.54	0.13 (± 0.68)	0.68	75.94 ± 17.66	76.14 ± 17.06	76.14 ± 17.06	0.58
BMI [kg/m2]	28.16 ± 4.76	28.21 ± 4.85	0.05 (± 0.23)	0.66	31.39 ± 7.63	31.44 ± 7.33	0.05 (± 0.29)	0.71
Fat Mass [%]	38.99 ± 5.68	40.15 ± 4.88	1.16 (± 1.15)	0.05*	41.53 ± 6.34	40.31 ± 6.71	-1.22 (± 1.21)	0.05*
Fat-free Mass [kg]	39.81 ± 3.15	39.19 ± 3.70	-0.63 (± 0.57)	0.04*	41.30 ± 5.21	42.24 ± 5.50	0.94 (± 0.86)	0.04*
Lipid Profile								
TG [mg/dl]	204.36 ± 59.53	216.82 ± 58.21	12.45 (± 21.16)	0.22	187.70 ± 60.83	162.30 ± 46.83	-25.40 (± 23.93)	0.04*
TC [mg/dl]	201.27 ± 30.34	215.27 ± 33.88	14.00 (± 17.73)	0.11	210.90 ± 41.77	190.30 ± 53.30	-20.60 (± 18.85)	0.04*

Table 3. Continued.

	Moderate Intensity Group (MIG) (n = 11)				High Intensity Group (HIG) (n = 10)			
	Pre	**Post**	**Change (± 95% CI)**	**p value**	**Pre**	**Post**	**Change (± 95% CI)**	**p value**
Blood Pressure								
SBP [mmHg]	129.82 ± 20.36	127.64 ± 18.65	-2.18 (± 8.14)	0.56	138.10 ± 24.14	133.50 ± 22.26	-4.60 (± 7.68)	0.21
DBP [mmHg]	76.0 ± 12.3	73.27 ± 9.22	-2.73 (± 3.82)	0.14	81.9 ± 13.71	77.40 ± 15.06	-4.50 (± 4.35)	0.04*
Resting HR [bpm]	72.64 ± 8.05	76.45 ± 8.66	3.82 (± 5.09)	0.13	72.80 ± 11.35	74.00 ± 8.89	1.20 (± 4.34)	0.55
Quality of Life								
QoL-General	62.50 ± 13.69	64.77 ± 12.27	2.27 (± 3.40)	0.17	55.00 ± 19.72	60.00 ± 19.36	5.00 (± 7.54)	0.17
QoL-Physical	68.18 ± 15.69	67.53 ± 17.01	-0.65 (± 5.86)	0.81	50.36 ± 15.47	57.14 ± 16.75	6.79 (± 5.04)	0.01*
QoL-Psychological	69.32 ± 15.17	74.24 ± 12.33	4.92 (± 3.93)	0.02*	58.33 ± 16.32	65.00 ± 13.78	6.67 (± 5.48)	0.02*
QoL-SR	71.21 ± 14.12	70.45 ± 15.53	-0.76 (± 8.84)	0.85	68.33 ± 16.10	70.83 ± 14.30	2.50 (± 6.91)	0.43
QoL-Environment	64.77 ± 13.04	66.19 ± 12.17	1.42 (± 3.02)	0.32	54.06 ± 10.83	59.06 ± 10.77	5.00 (± 6.76)	0.13

* $p<0.05$; *BMI* Body Mass Index; *BP* Blood Pressure; *CI* Confidence Interval; *CMJ* Countermovement Jump; *CST* Chair Stand Test; *DBP* Diastolic Blood Pressure; *HR* Heart Rate; *MBT* Medicine Ball Throw; *QoL* Quality of Life; *SBP* Systolic Blood Pressure; *SR* Social Relationships; *TC* Total Cholesterol; *TG* Triglycerides

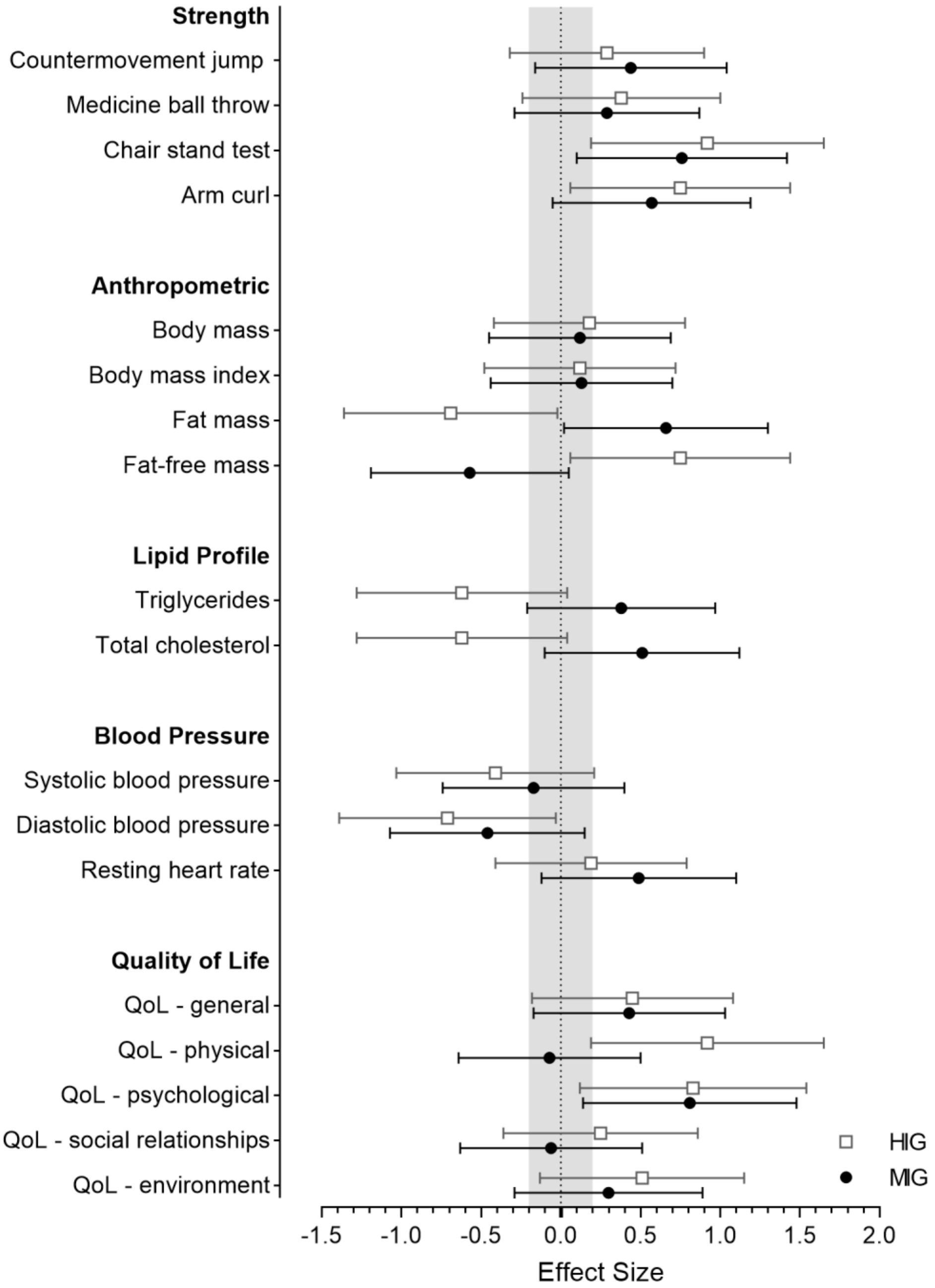


Figure 2. Standardized differences (effect size) between Post and Pre values of muscle strength, body composition, lipid profile, blood pressure, and quality of life (QoL) variables in the high-intensity (HIG) and moderate-intensity (MIG) water aerobics program. The trivial effect size interval is grey-colored. Error bars indicate 95% confidence interval.

Secondary outcome

The results of the study revealed a significant interaction between group and time for physical QoL, with a moderate effect size ($F = 4.56$, $p = 0.05$, $\eta_p^2 = 0.19$), indicating a preference for the HIG. No significant interactions group x time were observed in the other domains: general ($F = 0.59$, $p = 0.45$, $\eta_p^2 = 0.03$); psychological ($F = 0.35$, $p = 0.56$, $\eta_p^2 = 0.02$); social relationships ($F = 0.41$, $p = 0.53$, $\eta_p^2 = 0.02$); and environment ($F = 1.27$, $p = 0.27$, $\eta_p^2 = 0.06$). Additionally, a significant time effect was found in the psychological QoL domain, suggesting improvement in both groups, in addition to a significant group effect observed in physical QoL, favoring the HIG. However, no main effects were detected in the domains of general QoL and general health, social relationships, and environment. The ES values observed in Figure 2 demonstrate favorable large effects on the physical QoL in HIG (ES = 0.92), while both groups revealed positive large effects on the psychological QoL (MIG, ES = 0.81; HIG, ES = 0.83).

Discussion

The primary purpose of this study was to evaluate the effects of engaging in water aerobics for 12 weeks at different intensities (moderate versus high) on muscle strength, body composition, lipid profile, BP, and QoL in both adults and older adults. Our findings indicate that both exercise intensities led to significant and positive improvements in upper and lower muscle endurance and the psychological domain of QoL. However, the HIG was found to yield superior benefits in several areas, including body composition (fat and fat-free mass), lipid profile (TG and TC), and physical QoL, when compared to MIG. Additionally, diastolic BP was improved only after HIG. These results partially confirm our hypotheses that both interventions would yield positive adaptations and that higher exercise intensity would be associated with higher improvements. Although changes in several outcomes did not reach significance, most showed a trend toward improvement.

Regarding explosive strength, it appears that a longer intervention duration may be necessary to produce meaningful improvements through water aerobics. In contrast to our findings, Neiva et al. (2018) reported significant gains in upper limb explosive strength after 12 weeks of moderate-intensity water aerobics (approximately 65% of HR_{max}). The discrepancy between our results and those of Neiva et al. (2018) is likely due to the slightly longer session durations and possibly different exercise protocols employed in their study. In our study, we found some indications that upper limb explosive strength was marginally higher when performed at HIG, and the lower limbs were barely more enhanced with MIG. However, these changes were not statistically significant in either group. Overall, the intensity does not appear to be the primary variable influencing strength gains with water aerobics. This is consistent with the idea that water-based exercise may not provide sufficient mechanical load to elicit significant increases in explosive strength, which typically requires greater external resistance or impact (Colado et al., 2009). Factors such as exercise duration, the inclusion of specific strength-training components, and the mechanical resistance offered by the water should be considered in future research to better understand how water aerobics can effectively improve explosive strength in adults and older adults.

The HIG was found to reduce FM and increase fat-free mass, which aligns with previous research on similar aquatic programs and their effects on body composition (Irandoust & Taheri, 2015; Kantyka et al., 2015). Notably, the study did not control the diet. Previous research suggests that a controlled diet, in addition to high-intensity water aerobics, would further enhance body composition (Jasiński et al., 2015; Penaforte et al., 2015). However, in contrast, the MIG in the study increased FM and lost fat-free mass during the intervention period. This suggests that water aerobics performed at 60-70% HR_{max} can only enhance these variables with dietary control, as suggested by previous research (Jasiński et al., 2015). In this intensity, it's possible that the execution velocity of exercises wasn't sufficient to significantly impact these variables (Penaforte et al., 2015). The considerably lower baseline anthropometric values in the MIG may also have made it difficult to see improvements compared to the HIG. Regarding body mass and BMI, both groups were incapable of observing changes, corroborating the findings of Neiva et al (2018). There were probably no changes because, in both groups, although FM decreased/increased, the opposite happened in fat-free mass, approximately in the same proportion. These findings emphasize the importance of high-intensity exercise when aiming to improve FM and fat-free mass, in addition to the inefficacy of this training variable in body mass and BMI in adults and older adults. Thus, more research is needed to confirm the effects of water aerobics intensity and anthropometry.

The HIG led to improvements in the lipid profile, particularly TC and TG. These findings are noteworthy, as elevated levels of these lipids increase the risk of cardiovascular disease (Magalhães, 2017). On the other hand, MIG did not show changes in the lipid profile. Previous studies have reported no changes in cholesterol and TC following a moderate-intensity program with the same duration (Arca et al., 2014, Neiva et al., 2018). These results suggest the potential value of higher intensities of water aerobics, as well as the uncertainty surrounding the effects of moderate intensities (Kraus et al., 2002; Sigal et al., 2007). Additionally, Viljoen and Christie (2011) found no changes in the lipid profile but did not achieve adequate reductions in body mass. In contrast, Kasprzak and Pilaczyńska-Szcześniak (2014) reported improved cholesterol levels, which were concurrent with improvements in body composition. In our study, the HIG showed significant improvements in both the lipid profile and body composition, while the MIG did not. Therefore, the effects of cholesterol and TC on body composition, particularly reduced body fat, may be related to the intensity of the exercise (Irandoust & Taheri, 2015). HIG positively influenced body fat, which may explain the improved TC and TG levels observed in this group. These findings suggest that exercise intensity is crucial in improving TC and TG levels with water aerobics.

BP results were analyzed, and a significant group effect was detected, indicating that the HIG exhibited substantial improvements in diastolic BP. This finding is consistent with previous studies that have reported similar reductions in both systolic and diastolic BP in hypertensive individuals (Terblanche & Millen, 2012). However, in our sample of non-hypertensive individuals, only diastolic BP decreased significantly (5.6%). Although some participants improved systolic BP in HIG and MIG (evidenced by the absolute difference of approximately 3% and 1%, respectively), the mean difference did not reach statistically significant levels. The same happened with diastolic BP in MIG, with a non-significant reduction of around 3%. It is noteworthy that even small reductions in both systolic and diastolic BP are associated with decreased cardiovascular events (Igarashi & Nogami, 2018). Furthermore, previous studies have reported a higher likelihood of improving BP in hypertensive individuals (Pescatello et al., 2004), highlighting the changes achieved in our study involving normotensive individuals. Probably the decrease in the activity of the sympathetic nervous system and the increase in the action of the parasympathetic nervous system contributed to this reduction (Nahimura et al., 2008). Thus, the intensity of water aerobics seems to be important in the gains in diastolic BP.

We were unable to demonstrate a difference between groups in resting HR. Contrary to the findings of Igarashi and Nogami (2018), we anticipated a reduction in resting HR resulting from enhanced parasympathetic activity, a common response to warm water immersion (Bergamin et al., 2015). However, this reduction typically occurs with water temperatures in the range of approximately 36°C, which differs from the temperature used in the present study (29°C). This disparity may explain the absence of a reduction in resting HR. Therefore, the intensity of water aerobics does not appear to have a significant impact on resting HR, with water temperature playing a more prominent role in this phenomenon.

The HIG demonstrated a substantial improvement in the physical domain of QoL, while both groups experienced substantial improvements in the psychological domain. Furthermore, the HIG resulted in greater score improvements in the remaining quality-of-life domains, although no differences between groups. A study by Ayán et al. (2017) found that high-intensity aquatic exercise led to greater improvements in the QoL for healthy women. Consequently, high-intensity water aerobics may be a more effective means of improving QoL. Additionally, Garrido et al. (2016) suggested that 24 weeks of water aerobics improved QoL, but no information was provided about the intensities used. However, the psychological domain did not show any significant changes. Although the literature is limited on this variable, the promising results warrant further investigation.

The potential limitations of our study must be acknowledged. Specifically, the lack of a control group in our study design presents a limitation. The inclusion of a control group would have allowed us to establish a baseline for comparison, providing a clearer understanding of the effects observed. Without a control group, it is difficult to completely rule out the possibility that some of the improvements observed in both groups could be partially attributed to external factors unrelated to the exercise intervention, such as lifestyle changes or other health behaviors. Future studies should consider including a control group to better isolate the effects of different exercise intensities and clarify the unique contribution of aquatic exercise to the observed health outcomes. Furthermore, the small sample size within each experimental group warrants caution in the interpretation and generalization of our findings. The limited number of participants increases the risk of type II errors and may compromise the detection of significant differences between groups. This limitation is particularly relevant when considering the generalizability of our findings to the broader population of older adults, including both men and women. A larger sample size would provide more statistical power and improve the robustness of the findings, enhancing their relevance to wider populations. Nonetheless, it is important to recognize that we are dealing with a long-term follow-up, which is often challenging in populations of the age group studied here. However, the extended follow-up provides a comprehensive understanding of long-term effects, even with a small sample size in each group. Future studies should include a larger sample size to clarify some of the findings. Although most water aerobics participants in Portugal are women, the absence of men in our study may limit the generalizability of the results.

The lack of diet monitoring could have influenced our findings, particularly regarding body composition and lipid profile outcomes. For example, participants with healthier diets might have experienced greater improvements in TC and FM, while those with less healthy diets might have seen smaller benefits. Consequently, the variability in dietary habits might have contributed to the differences or lack of significant findings in some of the measured outcomes. However, it is important to note that the decision not to control diet was intentional and aligned with the pragmatic nature of our trial. Our primary aim was to assess the effects of different exercise intensities in a real-world setting, where dietary habits typically vary among individuals. By not controlling for diet, we aimed to replicate a more naturalistic environment, reflecting how water aerobics might impact health outcomes in everyday life.

Additionally, we did not assess cardiorespiratory fitness, which would have been informative given the aerobic nature of the intervention. This limits our understanding of how different intensities of water aerobics might affect cardiovascular health in older adults. Nonetheless, we prioritized other relevant variables, such as muscle strength and power, due to the heightened risk of sarcopenia in older adults. Future studies should incorporate measures of cardiorespiratory fitness and balance, while also including both sexes, controlling for potential confounding factors, and considering the stratification of participants by baseline fitness or physical activity levels for a more comprehensive understanding of the impact of aquatic exercise. While this study provides valuable insights into the role of exercise intensity in aquatic aerobics for older adults, addressing these limitations in future research will strengthen the evidence base and enhance the applicability of the findings in real-world settings.

In conclusion, HIG resulted in significant enhancements in lipid profile, physical QoL, and body composition by reducing FM and increasing fat-free mass, as compared to MIG. HIG also boosted upper and lower limb muscular endurance, and psychological QoL, while reducing diastolic BP. Conversely, while MIG did increase upper and lower limb endurance and psychological QoL, it was insufficient to significantly improve body composition. Neither intensity had a meaningful effect on explosive strength. Therefore, while exercise intensity is indeed a critical training variable when designing and evaluating water aerobics programs, future studies with more diverse and larger populations, longer intervention periods, and controlled dietary intake are needed to validate and expand upon these results.

Perspective

The popularity of exercise in aquatic environments has increased exponentially over the last decade, with a growing number of participants. Health and sports professionals usually recommend aquatic programs such as water aerobics due to the benefits of the water environment, which can potentially improve health and physical fitness. However, some studies fail to report or monitor exercise intensity, leading to inconclusive results. Additionally, no studies have explored the differences between different intensities (i.e., moderate vs. high-intensity) workouts in water aerobics. Results showed that both intensities of exercise improve muscular endurance and psychological QoL. Nevertheless, higher-intensity water aerobics can be more effective in improving body composition, lipid profile, physical QoL, and diastolic BP than moderate-intensity exercise. Thus, the intensity of exercise is a significant factor in achieving optimal outcomes in water aerobics for adults and older adults. This study provides sports professionals with guidance on the appropriate intensity levels to achieve desired health and fitness goals. Future studies should investigate more variations in intensity (i.e., low vs. moderate vs. high intensity) and longer intervention periods to understand water aerobics trends and effects.

Study 3. The Role of Exercise Intensity in Water Aerobics: Improving Health Markers in Adults - A Randomized Controlled Trial

Abstract

The lack of sufficient data on the intensity levels required for water-based exercise to produce desired results makes it critical to understand the effects of different intensities used in water aerobics. Thus, this study aimed to determine the effects of 24 weeks of moderate- and high-intensity water aerobics on physical fitness, cardiovascular health, and well-being in adults. Twenty women (67.10 ± 9.08 years) were randomized into two groups, each of whom performed water aerobics twice a week for 24 weeks. One group performed at moderate intensity (MIG; n = 10), while the other group performed at high intensity (HIG; n = 10). Participants were evaluated before and after the program. Assessments included muscle endurance, explosive strength, body mass, body mass index, fat mass, fat-free mass, triglycerides, total cholesterol, blood pressure, resting heart rate, general quality of life (QoL), general health, and the physical, psychological, social relationships, and environmental domains of QoL. Fat mass ($\eta_p^2 = 0.35$; $p = 0.01$), fat-free mass ($\eta_p^2 = 0.30$; $p = 0.01$), total cholesterol ($\eta_p^2 = 0.34$; $p < 0.01$), and triglycerides ($\eta_p^2 = 0.24$; $p = 0.03$) showed greater improvement with HIG than with MIG. Both exercise intensities improved muscular endurance, but only HIG reduced diastolic BP and improved physical QoL. High-intensity water aerobics is more effective than moderate-intensity water aerobics in improving certain health markers, including body composition, lipid profile, diastolic BP, and physical QoL. In addition, both intensities improved muscular endurance. Water aerobics is an exercise suitable for adults that improves physical fitness and cardiovascular health, with exercise intensity playing an important role.

Keywords: Aquatic exercise, intensity, physical fitness, health-related, quality of life

Introduction

Water aerobics has gained popularity due to its unique characteristics, involving a variety of movements performed in water. The water provides resistance and reduces the force of gravity on the body, creating an environment that can facilitate exercise interventions and may lead to significant improvements in physical performance (Butts et al., 1991; Neiva et al., 2018). In addition, the properties of water reduce the impact on joints, which can be particularly beneficial for people with joint pain or mobility problems (Moreira et al., 2018). These characteristics make aquatic exercise suitable for healthy individuals (Benelli et al., 2004; Colado et al., 2009a), those with certain health conditions (Faíl et al., 2022), as well as the elderly and those with no limitations (Raffaelli et al., 2016). This activity has been shown to improve several health and physical fitness parameters (Broman et al., 2006; Pöyhönen et al., 2002; Takeshima et al., 2002; Tsourlou et al., 2006).

In adults and older adults, significant improvements are usually seen with water aerobics programs of 12 to 24 weeks, performed 2–3 times per week for 45-60 minutes per session (Alves et al., 2004; Colado et al., 2009a; Garrido et al., 2016; Kantyka et al., 2015; Moreira et al., 2018; Neiva et al., 2018; Takeshima et al., 2002; Tsourlou et al., 2006). Cardiorespiratory fitness, strength, and balance appear to be positively improved in both healthy adults and those with chronic conditions (Faíl et al., 2022; Neiva et al., 2018). Moreover, water aerobics appears to positively affect health markers that are critical to cardiovascular health and overall well-being. Previous findings suggest that water aerobics leads to reductions in total cholesterol (TC) levels and beneficial effects on blood pressure (BP) regulation (Faíl et al., 2022; Neiva et al., 2018). However, studies on these markers remain scarce. Most studies focus primarily on the effects of these programs on muscle strength and body composition (Alves et al., 2004; López et al., 2017; Jasiński et al., 2015; Kantyka et al., 2015; Moreira et al., 2018; Neiva et al., 2018), with less emphasis on other parameters, such as lipid profile, BP, and quality of life (QoL) (Garrido et al., 2016; Kantyka et al., 2015; Kruel et al., 2021; Moura et al., 2020; Neiva et al., 2018). Understanding the effects of water aerobics on these variables is essential, as they are directly related to cardiovascular health and overall well-being (Lewington et al., 2002; Magalhães et al., 2017; Sampaio & Ito, 2013).

It is also important to determine the optimal intensity at which adults and older adults should perform water aerobics to induce substantial changes. The current literature provides limited information on this topic (Faíl et al., 2022). In particular, an 8-week study found that low-intensity water aerobic exercise was insufficient to improve body composition in adults and older adults (Jasiński et al., 2015). However, there is a paucity of long-term studies evaluating the effects of water aerobic exercise on these populations, particularly those comparing outcomes at different intensities, such as moderate versus high intensity. While high-intensity water aerobics may offer greater benefits for muscular and cardiovascular health, these findings are often derived from short-term studies or those with limited sample sizes (Costa et al., 2018; Neiva et al., 2018). Moreover, there are few studies assessing the effects of water aerobics on adults and older adults over a longer period of time. One of the few long-term studies available showed improvements in cardiovascular capacity and BP after a 24-week program, but it did not compare different levels of intensity (Piotrowska-Całka, 2010). This gap in the literature makes it difficult to determine the potential benefits and harms of water aerobics at different intensity levels. More research is needed to determine whether longer programs and different intensities have a greater impact on the health and well-being of adults.

Therefore, the aim of the present study was to compare the effects of a long-term water aerobic exercise program - 24 weeks - performed at moderate intensity with a similar program performed at high intensity on muscle strength, anthropometry, lipid profile, BP, and QoL in adults. It was hypothesized that most of the variables analyzed would show improvements after 24 weeks of training, regardless of the intensity used. In addition, it was also hypothesized that all of the analyzed parameters would show better results after 24 weeks of high-intensity water aerobics compared to the moderate-intensity program.

Material and Methods

Experimental design and participants

In the current pragmatic randomized controlled trial (pRCT) (Registration in ClinicalTrials.gov: NCT06529354), participants were randomly assigned to two experimental groups. Both groups performed water aerobics for 24 weeks. One group performed water aerobics at moderate intensity (MIG), while the other group performed it at high intensity (HIG). The main purpose of this study was to assess the effects of moderate- and high-intensity water aerobics on physical fitness, cardiovascular health, and well-being in adults.

Participants were recruited from the Municipal Swimming Pool of Tramagal, Abrantes, Portugal. After receiving instructions on the purpose of the study, the subjects agreed and signed the informed consent form. Participants were instructed to maintain their usual eating habits, although their dietary intake was not specifically assessed. To be eligible for the study, all participants had to be at least 18 years old and attend two classes per week. In addition, participants could not have been recently hospitalized, have severe cognitive or motor problems, have any medical restrictions on performing physical activity, or be participating in another physical activity program. Being male was not considered an exclusion criterion, although only women participated in the study. This research was reviewed and approved by the Ethics Committee of the University of Beira Interior, Portugal (CE-UBI-Pj-2019-051 in October 2019).

This study was implemented in accordance with the Declaration of Helsinki. The authors followed the CONSORT reporting guidelines (Schulz et al., 2010).

Of the 29 individuals assessed for eligibility, three declined to participate in the study, and two did not fulfill the inclusion criteria. Consequently, 24 eligible participants were enrolled in the study, with 12 being randomly assigned to the HIG group and the other 12 to the MIG group. Over the course of the 24-week intervention period, four participants withdrew from the study. Three participants (two from MIG and one from HIG) withdrew due to injury. The nature of these injuries was not directly related to the aquatic exercise sessions, or the tests used but were due to external factors. One participant in the HIG group withdrew after the pre-test evaluations due to an illness unrelated to the study protocol. No serious adverse events were reported and there was no evidence of injury from the intensity of the exercise. Ultimately, 20 women completed the study, with 10 assigned to the HIG and the other 10 to the MIG. Participants were required to attend two sessions per week, with an overall adherence rate of approximately 90% (mean ± SD: 90.20 ± 0.06%) for the 48 sessions, indicating good compliance with the intervention protocol. For a more detailed representation of the participant flow throughout the study, please refer to Figure 1.

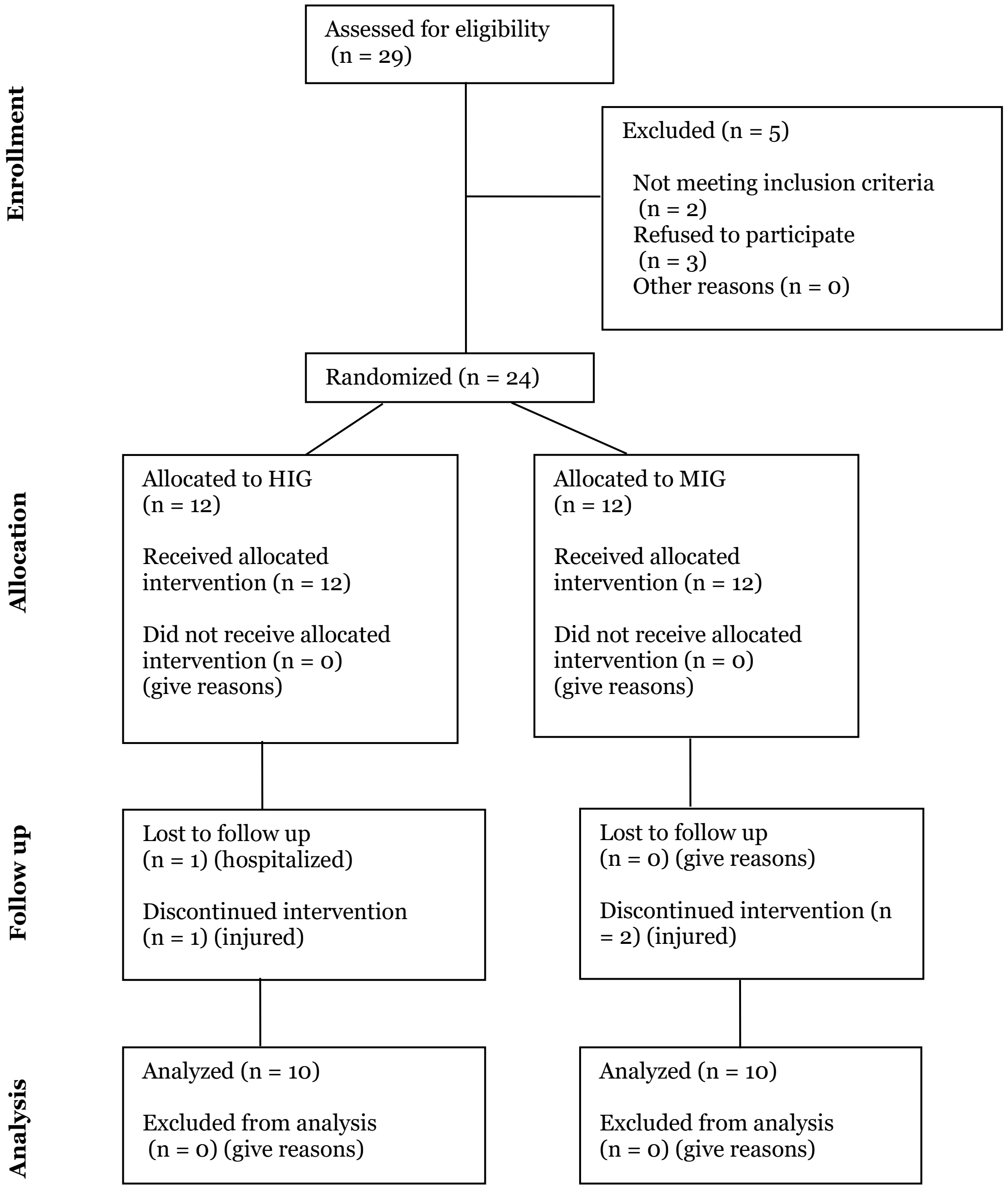


Figure 1. Participant flow diagram throughout the study. HIG High Intensity Group; MIG Moderate Intensity Group.

Intervention

Each subject performed the exercise program twice a week for 24 weeks. Each class lasted 45 minutes and took place in a 1.50 m deep pool with water at 29.0 °C. Classes included a 5-minute warm-up (e.g., walking back and forth, performing lateral movements, stretching all major muscle groups), 30 minutes of exercise (e.g., jogging, side steps, swings, kicks, jumps, squats, hip flexion, extension, abduction and adduction, scissors, bicycle), and a 5-minute of cool-down (e.g., walking back and forth, performing lateral movements, stretching all major muscle groups). Some equipment was commonly used in the training, such as dumbbells, water noodles, etc. The MIG classes were performed at moderate intensities, between 60% and 70% of the aged-predicted maximum heart rate (HR_{max}) (HR_{max} = 207- 0.7 x age) (Gellish et al., 2007). After calculating the HR_{max}, we assessed the resting HR of all participants in two conditions: out of the water and in the water. We then subtracted the resting HR measured in the water from the resting HR recorded out of the water. Finally, we deducted this difference from the HR_{max} value obtained using the formula established by Gellish et al. (2007). The MIG presented HR values of 86.80 ± 7.00 bpm during warm-up, 112.46 ± 4.89 bpm during exercise, and 91.55 ± 4.90 bpm during cool-down. The HIG performed water aerobics classes at high intensities, between 80% and 90% of the aged-predicted HR_{max}, and recorded a HR of 96.35 ± 9.35 bpm during warm-up, 132.71 ± 6.37 bpm during exercise, and 101.95 ± 7.38 bpm during cool-down. The intensity of the classes was controlled by musical cadence (Barbosa et al., 2010; Costa et al., 2011), 100-125 and 135-160 beats per minute in the MIG and HIG classes, respectively (Barbosa et al., 2010). In addition, the HR was recorded during training once every two weeks to ensure that the intensity range was adhered to. During these sessions, a HR monitor (Polar H10, Kempele, Finland) connected via Bluetooth to a Polar watch was used. Several researchers evaluated the participants HR at the end of the warm-up and cool-down and every three minutes during the main part of the exercise. Before the start of the study, the water aerobics lessons instructor was informed about the purpose of the study and was not pressured to condition the instructor's activity. Also, the exercises performed during the program were those commonly used before the start of the study, varying only in the intensity used in each group.

Outcome measures

To understand the effects of 24 weeks of water aerobics in adults, muscle strength, anthropometry, lipid profile, and BP were evaluated as primary outcomes, with QoL as a secondary outcome. These variables were assessed in the week before the start of the program (Pre), and in the week after the completion of the program (Post). For each assessment moment, participants were assessed on two different days separated by 72 hours. On the first day, body composition, BP, and explosive strength were assessed in that order. On the second day, lipid profile, muscle endurance, and QoL were assessed. The researchers, the assessment conditions, and the order in which the tests were performed were always the same at all assessment times. Participants were always encouraged to perform as best as possible in all assessments.

Explosive strength

The explosive strength of the upper and lower limbs was assessed by the medicine ball throw (MBT) and the countermovement jump (CMJ), respectively. For the 3 kg MBT (Vinex model VMB-003R, Bhalla International, Delhi, India), the participants performed 3 throws with the goal of achieving the maximum distance possible, with 3 minutes of rest between each attempt

(Harris et al., 2011). To complete the test, the subjects had to sit in a chair touching the wall, lean against the chair, place their feet on the floor and throw the ball. A tape measure was used to obtain the values. MBT performance showed an average intraclass correlation coefficient (ICC) of 0.86 (95% CI: 0.73-0.93) and coefficient of variation (CV) values of 2.11%.

In the CMJ, subjects performed 3 countermovement vertical jumps with a 2-minute rest between each trial. For this, the subjects placed themselves inside an Optojump platform (Optojump, Microgate, Bolzano, Italy) and jumped from a standing position with their feet shoulder-width apart and their hands on their hips (Ramírez-Campillo et al., 2017). The mean values of each subject were considered in CMJ and MBT. CMJ performance showed a mean ICC of 0.94 (95% CI: 0.88-0.98) and CV values of 5.86%.

Endurance strength

The arm curl test was used to access upper limb endurance strength. In this measurement, participants held a 2 kg dumbbell with the dominant hand, performed a full forearm flexion, and returned to the initial forearm extension position, while seated, leaning against a chair with their feet flat on the floor. Subjects were instructed to perform this movement as many times as possible for 30 seconds, counting only the correct repetitions of the movement (Rikli & Jones, 1999).

On the other hand, the chair stand test (CST) was used to measure lower limb endurance strength. In this test, participants sat in a chair and, at the start signal, rose to the maximum extension, then returned to the starting position and performed the maximum number of repetitions that they could in 30 seconds. To perform the test correctly, individuals should sit back in the chair with their feet flat on the floor and shoulder-width apart, while keeping their upper limbs crossed at the wrist and against the chest. Upper and lower limb endurance strength was assessed using Rikli and Jones (1999) test battery.

Anthropometry

The anthropometric parameters assessed were body mass, body mass index (BMI), fat mass percentage (FM), and fat-free mass. Body mass, FM, and fat-free mass values were obtained using a bioimpedance balance (Tanita, BC418 Ma, Tokyo, Japan). BMI was obtained by dividing the body mass value by the square of the height. Height was measured using a precision stadiometer with a scale of 0.001m (Seca 213, Hamburg, Germany). All these parameters were measured with the participants standing barefoot and wearing as little clothing as possible (Marfell-Jones et al., 2012). Prior to the device measurements, all participants were instructed to adhere to the following guidelines to enhance the accuracy and consistency of the device measurements: no exercise for 12 hours prior; no urination for 30 minutes prior; no alcohol or caffeine for 48 hours prior to the measurement. Additionally, the assessments were conducted in the morning at the same time for both pre- and post-tests. Although participants were advised not to eat or drink anything 4 hours before the test, the nature of the study (pragmatic) made it impossible to control for this factor. However, if participants consumed any substances prior to the test, the authors recommended that they replicate the same meal and timing for both assessments and suggested that it should be a light meal.

Lipid profile

Triglycerides (TG) and TC were assessed by taking blood samples from the participants' fingertips using special lancets and strips (Accutrend Plus, La Roche, Germany). After resting for 15 minutes, blood samples were taken before exercise and at least 2 hours after the last meal. After disinfecting the site with 70% alcohol, a figertip was punctured with a disposable lancet (Accu-Chek Aviva Test Strips). The first drop of blood was discarded to avoid possible contamination with sweat. A blood sample was then collected on a test strip and inserted into the device for analysis.

Blood pressure

BP was measured after the participants rested for 20 minutes. Systolic and diastolic BP and resting HR were measured twice using an automatic BP monitor (OMRON M4-1, Hoofddorp, The Netherlands) (American College of Sports Medicine et al., 2013). The second measurement was used for analysis. All measurements were performed with the participants sitting in a chair.

Quality of life

The Portuguese version of the World Health Organization Quality of Life - Bref questionnaire (WHOQOL-BREF) was used to assess the subjects' QoL (Serra et al., 2006). For this purpose, 26 questions were applied, two of which were related to the general QoL and general health of the participants, while the other 24 items were intended to classify their perception of QoL. These 24 questions were divided into four domains: physical, psychological, social relationships, and environment. The domain scores were transformed into a linear scale between 0 and 100 (Serra et al., 2006), with a higher score corresponding to a higher QoL.

Randomization

The research was conducted as a double-blind pRCT, in which participants were unaware of the experimental group to which they were assigned. The participants were assigned using a simple randomization method. Participants were randomly assigned to the study groups in a 1:1 ratio using a computer-generated list of random numbers. Each number corresponded to a sealed opaque envelope containing information about the study group, ensuring that the randomization process was concealed. The sequential numbers were not revealed until the interventions were assigned. Randomization was performed by three authors, and the researcher responsible for assigning participants to specific groups had no prior knowledge of the treatment each participant would receive. Due to the nature of the study, neither the instructor nor the main researcher involved in the assessments and training were blinded. However, the research team conducting the evaluation, including the pre- and post-test assessments, was also blinded to the details to maintain impartiality.

Statistical analysis

Based on the results of a previous study by Neiva et al. (2018) a sample size of twenty participants would be required to achieve a power of 80%. This assumes an alpha level of 0.05, a Cohen's f of 0.36, two groups, and two assessments (pre- and post-test for the primary outcomes). Calculations were performed using G*Power v3.1 (Kang, 2021). Statistical analysis was performed using the Statistical Package For Social Sciences (IBM SPSS Statistics for Windows, version 28.0, IBM Corp. Armonk, NY, USA). Standard statistical procedures were selected to calculate means, standard deviations, and 95% confidence limits. The Shapiro-Wilks test ($n < 30$) was used to test normality, and the Levene test to confirm the homogeneity of variances. ICC and CV was used to assess the reliability of the three trials performed, which was calculated with a bidirectional mixed random effects model (absolute agreement type). The consistency of the measurements was assessed by the ICC, and the CV provides an additional indicator of reliability. An independent samples t-test was performed to compare each variable at baseline between groups. A two-way mixed design analysis of variance (ANOVA) with one factor with repeated measures (pre-test and post-test) was used to analyse the changes over time and differences between groups. In addition, paired samples t-tests were used to perform a within-group analysis from pre-test to post-test. The level of statistical significance was set at p-value ≤ 0.05. Additionally, the effect size was calculated using the partial eta squared (η_p^2) to estimate the between-group variance, and Hedge's *g* (g) for within-subject comparisons (Cohen, 1988; Lakens, 2013). The η_p^2 values were considered small between 0.01 and 0.08, moderate between 0.09 and 0.24, and large above 0.25. g values were classified as small between 0.20 and 0.49, moderate between 0.50 and 0.79, and large above 0.80.

Results

At baseline, there were no significant differences between the groups for any of the variables analyzed (all $p > 0.05$). For more details on the characteristics of the study participants, see Table 1.

Table 1. Characteristics of the MIG and HIG study participants at baseline (mean ± SD).

Variable	MIG (n = 10)	HIG (n = 10)
Age [years]	65.50 ± 8.33	68.70 ± 9.94
Heigh [m]	1.59 ± 0.58	1.59 ± 0.75
Body mass [kg]	70.46 ± 11.02	77.46 ± 17.89
BMI [kg/m^2]	29.03 ± 4.90	32.02 ± 7.66
Fat mass [%]	39.72 ± 5.99	42.36 ± 6.35
Fat-free mass [kg]	40.26 ± 3.10	42.13 ± 5.24
Triglycerides [mg/dl]	206.80 ± 62.52	191.50 ± 60.78
Total Cholesterol [mg/dl]	200.30 ± 27.00	215.10 ± 41.85
Systolic BP [mmHg]	132.0 ± 21.27	140.90 ± 24.11
Diastolic BP [mmHg]	75.30 ± 10.47	83.50 ± 13.96

BMI Body Mass Index; *BP* Blood pressure; *HIG* High Intensity Group; *MIG* Moderate Intensity Group; *SD* Standard Deviation.

Primary outcomes

Table 2 provides a comprehensive overview of the specific variables assessed before and after the training sessions for both the MIG and HIG groups. No significant group x time interactions were observed for explosive strength of the lower and upper limbs (CMJ: $F = 0.39$, $p = 0.54$, $\eta_p^2 = 0.02$; MBT: $F = 0.92$, $p = 0.35$, $\eta_p^2 = 0.05$) and in the endurance strength of the lower and upper limbs (CST: $F = 1.52$, $p = 0.23$, $\eta_p^2 = 0.08$; arm curl test: $F = 0.38$; $p = 0.55$; $\eta_p^2 = 0.02$). There was a significant time effect on muscular endurance, with both groups improving in the lower and upper limb strength assessments. No significant changes were found in the lower and upper explosive strength variables.

For body composition, significant group x time interactions with large effects were identified for FM ($F = 9.81$, $p = 0.01$, $\eta_p^2 = 0.35$) and fat-free mass ($F = 7.66$, $p = 0.01$, $\eta_p^2 = 0.30$), both with improvements in HIG. Here, with a significant group effect, FM decreased and fat-free mass increased, both in HIG. No interactions or main effects were found for body mass ($F = 0.05$, $p = 0.82$, $\eta_p^2 < 0.01$) and BMI ($F = 0.06$, $p = 0.81$, $\eta_p^2 < 0.01$).

In the lipid profile, significant group x time interactions were found for TC ($F = 9.11$, $p < 0.01$, $\eta_p^2 = 0.34$) and TG ($F = 5.60$, $p = 0.03$, $\eta_p^2 = 0.24$), with large and moderate positive effects for HIG, respectively. In addition, significant reductions in TC and TG were observed in the HIG.

There were no significant group x time interactions for diastolic BP ($F = 0.92$, $p = 0.35$, $\eta_p^2 = 0.05$), although a significant decrease was found in the HIG. Furthermore, systolic BP ($F = 0.42$, $p = 0.53$, $\eta_p^2 = 0.02$) and resting HR ($F = 0.02$, $p = 0.90$, $\eta_p^2 < 0.01$) showed no interactions or main effects.

The g values are shown in Figure 2. According to these results, the HIG had a greater effect than the MIG on several variables. The HIG group showed a large positive effect on arm curl, fat-free mass, and TG. The CST, MBT, FM, TC, and diastolic BP also showed moderate effects in this group. Although both groups showed a positive effect on the arm curl, only this variable demonstrated superior results after the MIG group compared to the HIG, with large effects. However, the MIG group showed medium negative changes in FM, TC, and resting HR.

Table 2. Muscle strength, anthropometric, lipid profile, blood pressure, and quality of life values of the Moderate Intensity Group and High Intensity Group in the pre- and post-training.

	Moderate Intensity Group (MIG) (n = 10)				High Intensity Group (HIG) (n = 10)			
	Pre	Post	Change (± 95% CI)	p value	Pre	Post	Change (± 95% CI)	p value
Strength								
CMJ [cm]	6.93 ± 3.58	7.66 ± 3.62	0.74 (± 1.10)	0.17	5.44 ± 3.57	5.81 ± 3.70	0.37 (± 0.73)	0.28
MBT [cm]	2.28 ± 0.29	2.32 ± 0.33	0.04 (± 0.14)	0.55	2.16 ± 0.42	2.29 ± 0.53	0.13 (± 0.17)	0.12
CST [reps]	14.69 ± 2.77	16.01 ± 2.79	1.32 (± 1.26)	0.04*	16.12 ± 5.96	19.07 ± 3.37	2.95 (± 2.71)	0.04*
Arm Curl [reps]	19.89 ± 2.97	22.44 ± 2.76	2.55 (± 1.32)	<0.01*	22.54 ± 7.48	25.91 ± 5.19	3.37 (± 2.73)	0.02*
Anthropometric								
Body Mass [kg]	70.46 ± 11.02	70.69 ± 10.63	0.23 (± 0.67)	0.46	77.46 ± 17.89	77.78 ± 17.72	0.32 (± 0.58)	0.25
BMI [kg/m2]	29.03 ± 4.90	29.15 ± 4.88	0.12 (± 0.26)	0.32	32.02 ± 7.66	32.10 ± 7.51	0.08 (± 0.26)	0.51
Fat Mass [%] #	39.72 ± 5.99	40.62 ± 5.78	0.90 (± 1.03)	0.08	42.36 ± 6.35	41.06 ± 7.02	- 1.30 (± 1.21)	0.04*
Fat-free Mass [kg] #	40.26 ± 3.10	40.19 ± 2.78	- 0.07 (± 0.52)	0.75	42.13 ± 5.24	43.17 ± 5.26	1.04 (± 0.77)	0.01*
Lipid Profile								
TG [mg/dl] #	206.80 ± 62.52	213.20 ± 48.86	6.40 (± 29.04)	0.63	191.50 ± 60.78	157.00 ± 35.77	- 34.50 (± 26.17)	0.02*
TC [mg/dl] #	200.30 ± 27.00	210.30 ± 18.74	10.00 (± 12.76)	0.11	215.10 ± 41.85	190.80 ± 37.00	- 24.30 (± 22.48)	0.04*

Table 2. Continued.

	Moderate Intensity Group (MIG) (n = 10)				High Intensity Group (HIG) (n = 10)			
	Pre	Post	Change (± 95% CI)	p value	Pre	Post	Change (± 95% CI)	p value
Blood Pressure								
SBP [mmHg]	132.00 ± 21.27	130.60 ± 13.61	- 1.40 (± 10.04)	0.76	140.90 ± 24.11	135.20 ± 19.14	- 5.70 (± 11.26)	0.28
DBP [mmHg]	75.30 ± 10.47	70.60 ± 04.50	- 4.70 (± 7.32)	0.18	83.50 ± 13.96	74.00 ± 11.31	- 9.50 (± 8.65)	0.04*
Resting HR [bpm]	73.50 ± 8.11	75.70 ± 7.06	2.20 (± 2.40)	0.07	74.30 ± 11.38	76.10 ± 11.86	1.80 (± 6.58)	0.55
Quality of Life								
QoL-General	62.45 ± 13.58	62.45 ± 18.13	0.00 (± 11.92)	1.00	56.10 ± 19.91	62.48 ± 17.18	6.38 (± 8.69)	0.13
QoL-Physical	68.48 ± 16.01	68.48 ± 20.81	0.00 (± 12.57)	1.00	51.37 ± 15.48	58.65 ± 15.19	7.28 (± 6.02)	0.02*
QoL-Psychological	70.12 ± 15.76	74.80 ± 13.93	4.68 (± 6.45)	0.14	59.50 ± 16.43	66.73 ± 13.40	7.22 (± 8.18)	0.08
QoL-SR	71.40 ± 14.56	73.11 ± 14.30	1.71 (± 10.77)	0.73	69.70 ± 16.11	71.40 ± 11.96	1.70 (± 11.17)	0.74
QoL-Environment	66.30 ± 13.95	65.67 ± 13.48	- 0.64 (± 7.74)	0.86	55.14 ± 10.98	59.29 ± 9.26	4.14 (± 7.90)	0.27

* p<0.05 for pre vs. post comparison within group; # p< 0.05 for group x time interaction; *BMI* Body Mass Index; *BP* Blood Pressure; *CI* Confidence Interval; *CST* Chair Stand Test; *CMJ* Countermovement Jump; *DBP* Diastolic Blood Pressure; *HR* Heart Rate; *MBT* Medicine Ball Throw; *QoL* Quality of Life; *SBP* Systolic Blood Pressure; *SR* Social Relationships; *TC* Total Cholesterol; *TG* Triglycerides

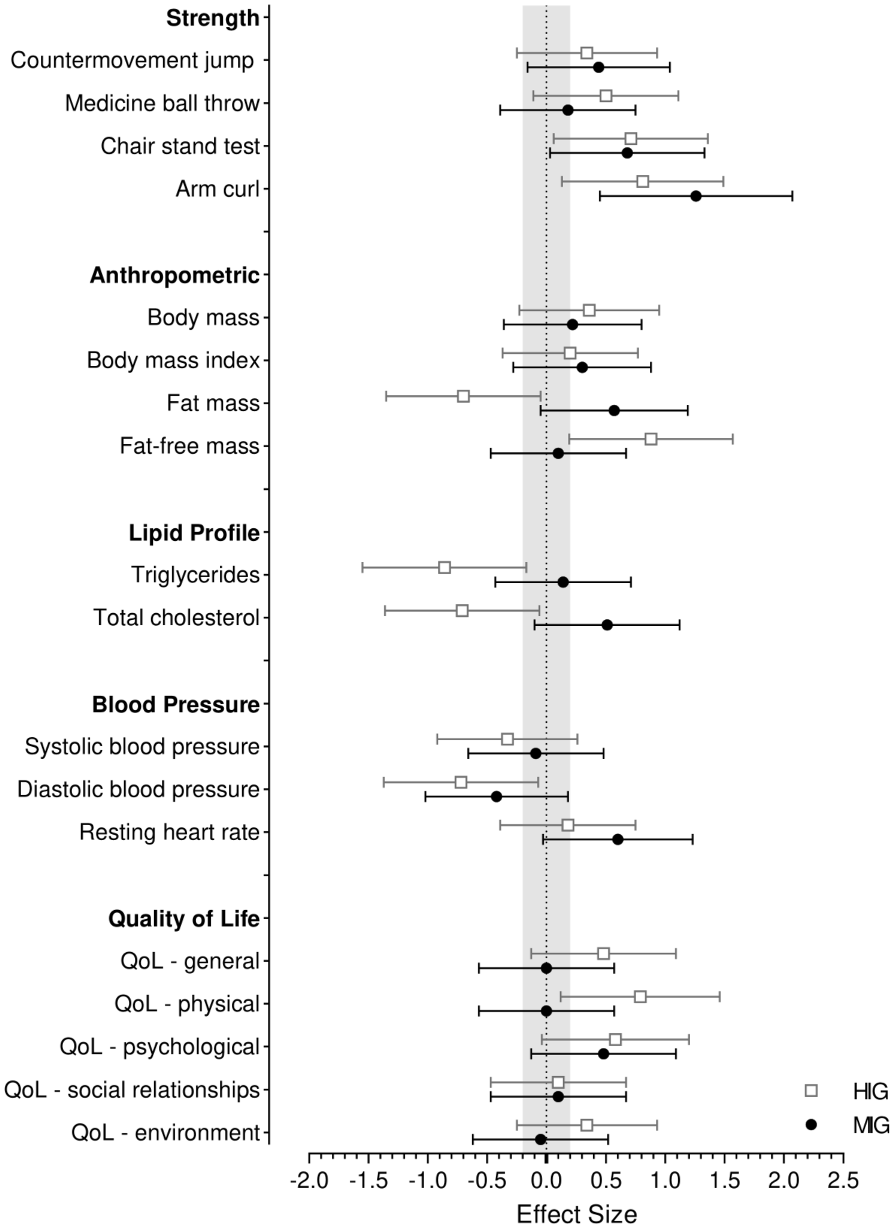


Figure 2. Within-group effect size (Hedge's *g* effect size) of Pre and Post values of muscle strength, anthropometry, lipid profile, blood pressure, and quality of life (QoL) variables in the High Intensity Group (HIG) and Moderate Intensity Group (MIG).

Secondary outcome

In general, no main effects were found in the domains of QoL, general health, psychological and social relationships, and environment. No significant group x time interactions were observed in any of the QoL domains (all $p > 0.05$). A significant improvement was observed in the physical domain of QoL in the HIG.

Discussion

The purpose of this study was to compare the effects of 24 weeks of moderate- versus high-intensity water aerobics program on muscle strength, body composition, lipid profile, BP, and QoL in adults. The results indicate that 24 weeks of water aerobics improved upper and lower muscular endurance. In addition, FM, fat-free mass, TG, and TC benefited more from HIG than from MIG. The high-intensity program also improved diastolic BP and physical QoL. Some of our hypotheses were partially confirmed, as both interventions led to improvements, with higher intensities producing better results. However, none of the intensities produced changes in explosive strength, body mass, BMI, systolic BP, resting HR, and general, psychological, social relationship, and environmental QoL.

No interaction between group and time was observed for endurance strength. However, a significant time effect was found, with both groups showing improvements in upper and lower limb strength after 24 weeks of exercise. Previous research has shown conflicting results, and lower-body endurance in postmenopausal women was found to improve after 24 weeks of water aerobic exercise, but upper-body endurance did not (Novaes et al., 2014). Although water aerobics tends to improve muscular endurance, intensity does not seem to be the main factor. The lack of improvements in explosive strength further supports this, as water aerobics appears to be insufficient to significantly improve explosive strength in the lower and upper limbs. In contrast, Tsourlou et al. (2006) obtained significant gains in lower explosive strength after 24 weeks of water aerobics, but with a program in which the intensity gradually increased, between 65% and 80% of the maximal HR. This suggests that both the intensity and the specific exercises performed in the water influence the results. Overall, these results raise the question of whether intensity is the primary training variable for optimizing explosive and endurance strength. Therefore, more research is needed on the importance of intensity, as well as other training variables (e.g., different exercises), to understand how to achieve greater gains during water aerobics exercises.

In terms of anthropometry, HIG significantly improved FM and fat-free mass, whereas no changes were found in the MIG. Similar results have been reported in other aquatic exercise programs of similar duration, which also showed substantial improvements in FM (Colado et al., 2009b) and fat-free mass (Colado et al., 2009b; Tsourlou et al., 2006). Water-based activities involve both the upper and lower extremities, allowing movements within optimal ranges of motion, minimizing joint stress, and potentially increasing exercise capacity, which may contribute to improved body composition in older adults (Irandoust & Taheri, 2015). However, the primary factor driving the improvements in FM and fat-free mass observed in this study is likely exercise intensity. Higher exercise intensity increases caloric expenditure and stimulates greater metabolic and muscular adaptations, leading to significant changes in body composition.

To the best of our knowledge, only one study has evaluated high-intensity aquatic exercise and demonstrated improvements in FM despite no change in fat-free mass (Penaforte et al., 2015). This study (Penaforte et al., 2015) primarily used an anaerobic regimen in their classes, whereas the present program likely focused more on the aerobic system. This suggests that the specific characteristics of aerobic or anaerobic aquatic programs may affect body composition, particularly fat-free mass (Penaforte et al., 2015). In contrast to the present findings for the MIG, most of the research literature has reported improvements in both FM (Neiva et al., 2018; Nuttamonwarakul et al., 2014) and fat-free mass (Kantyka et al., 2015; Tsourlou et al., 2006). In this study, the speed of execution may have been insufficient to significantly affect these variables (Penaforte et al., 2015). With respect to body mass and BMI, the current findings are supported by other studies (Novaes et al., 2014; Tsourlou et al., 2006) that show that 24 weeks of water aerobics, regardless of intensity, is not sufficient to produce changes in these measures. Thus, the intensity of water aerobics appears to have a greater effect on FM and fat-free mass than on body mass and BMI.

In terms of lipid profile, TC and TG, there were significant reductions with the HIG. These reductions achieved in the HIG may be related to the improvements seen in FM (Irandoust & Taheri, 2015). Reductions in these parameters are important because they are strongly associated with coronary heart disease, stroke, and type 2 diabetes (Kantyka et al., 2015). Studies have shown that aerobic exercise of sufficient intensity is necessary to induce favorable changes in lipid profiles. For example, Stein et al. (1990) suggested that a minimum intensity of 75% is required to improve high-density lipoprotein (HDL) cholesterol levels. Although HDL cholesterol was not measured in this study, a similar minimum intensity may be required to achieve significant results for TC and TG. The aerobic exercise characteristic of water aerobics, when performed at high intensity, combined with the effects of immersion in water, may account for the observed effect on the lipid profile (Costa et al., 2018). The importance of intensity is supported by previous studies showing no significant changes in TC and TG after 12, 14, and 24-week water aerobics programs performed at intensities below 75% (Kantyka et al., 2015; Neiva et al., 2018; Sobczak et al., 2023). The above highlights the importance of intensity in achieving the desired effects on the lipid profile of adults.

The results showed that there was no interaction on BP, but there was a significant effect on diastolic BP within the high-intensity program over 24 weeks. The effect of water aerobics on BP appears to vary depending on the population studied, and there is no consensus in the literature. When programs of the same duration (24 weeks) are used in nonhypertensive individuals, there appears to be a tendency to improve only diastolic BP (Novaes et al., 2014; Sobczak et al., 2023). On the other hand, there is a greater tendency for hypertensive individuals to reduce only their systolic BP after water aerobics exercise (Terblanche & Millen, 2012). Despite the lack of agreement, the ability to reduce BP is important because it is strongly associated with a reduction in the incidence of stroke and coronary heart disease (Touyz et al., 2014).

The potential risk of developing hypertension and facing higher cardiovascular mortality is usually associated with elevated resting HRs (Palatini et al., 1997). Because water aerobics is primarily an aerobic activity and there is limited research on the effects of resting HR in individuals with little training experience (Kravitz & Mayo, 2007), it was considered important to analyse this variable in this modality. Therefore, no interactions or main effects of resting HR were observed in this analysis. Similarly, 16 weeks of aquatic aerobic exercise was not sufficient to positively affect this variable (Green, 1989). Nevertheless, another 24-week water aerobics program identical to the present MIG achieved large reductions in resting HR (Piotrowska-Całka, 2010). In the same vein, Nuttamonwarakul et al. (2014) also found improvements in this parameter with a 12-week program in elderly women with type 2 diabetes mellitus but performing classes with water at 36ºC. Although not a general rule, one of the most important factors in achieving favorable results in resting HR during water aerobics appears to be performing classes in warm water (Bergamin et al., 2014; Nuttamonwarakul et al., 2014). Therefore, resting HR may be influenced by a combination of water temperature and exercise intensity.

No interactions were found for QoL outcomes. Furthermore, a significant group effect was found on the physical QoL, with positive effects after 24 weeks of high-intensity water aerobics. Similar water aerobics program also found improvements in physical QoL but did not provide details on the intensity used (Garrido et al., 2016). Although there were no differences in general QoL and general health, and in the psychological and environmental domains, there was some evidence that changes were greater in the high-intensity program, supporting the recommendation of Ayán et al. (2017) that water aerobics must be performed at high intensities to produce effects on the QoL.

One of the major strengths of the current study was that it examined the effects of water aerobic exercise in a real-world context. To this end, the instructor responsible for the classes was aware of the study, but received no external pressure to condition his activity. The instructor conducted the classes using exercises that he typically performed with the same participants before the study began but varied the intensity between classes. Despite this strength, several limitations must be acknowledged, such as the lack of dietary control and monitoring of participants' medications, and the non-participation of men. The main purpose of this study was to evaluate how different exercise intensities affect health outcomes in a real-world setting, taking into account the diversity of dietary habits and medication use among individuals. By deliberately not controlling for diet and medication, the study sought to more realistically reflect the daily variation in these factors and thus provide insight into the potential effects of water aerobics on overall health. It is important to interpret these findings with caution due to the limited number of participants in each experimental group. However, the extended follow-up period provides valuable insight into the long-term effects, despite the small sample size. We also acknowledge that some baseline differences between groups, although not statistically significant, may have contributed in part to the greater benefits observed in the HIG. Given the aerobic nature of the intervention, the authors could have assessed cardiorespiratory fitness. However, they chose to assess strength because of the significant risk of sarcopenia, a condition characterized by the loss of muscle mass. Sarcopenia is strongly associated with increased falls in adults and older adults (Yeung et al., 2019). In addition, other anthropometric assessment methods could have been used to enhanced the results of this study, including measurement of skinfolds, waist and hip circumference, and waist-to-hip ratio. Because of these limitations, researchers should analyse the present findings with caution. The results should be extended by future studies with larger and more diverse populations, greater variation in intensity, longer intervention periods, and controlled dietary intake.

Conclusions

The present study suggests that 45 min of high-intensity water aerobic exercise twice a week for 24 weeks improves lipid profile, FM, and fat-free mass, compared with the same program performed at moderate intensity. High intensity is also responsible for improvements in diastolic BP and physical QoL. In addition, both intensities produce favorable results in lower and upper muscular endurance. However, neither intensity induces substantial changes in explosive strength, body mass, BMI, systolic BP, resting HR, and general, psychological and social relationships, and environmental QoL. Overall, water aerobics appears to be an appropriate exercise modality for adults, with exercise intensity playing an important role in enhancing certain aspects of physical fitness and cardiovascular health, particularly in improving body composition, lipid profile, diastolic BP, and physical QoL. At the same time, both moderate and high intensity exercise are effective in improving muscular endurance. This research provides valuable advice for exercise professionals, outlining specific strategies for achieving optimal health and fitness goals by tailoring intensity levels to individual needs.

Study 4. Exploring the determinants of strength development in water aerobics: the program intensity, duration, fitness and participant characteristics

Abstract

The current study aimed to verify whether the muscle strength achieved from a water aerobics program is related to the program's intensity and duration, the participant's age, baseline measures of muscle strength, body composition, and quality of life. For that, this study analyzed data from two pragmatic randomized controlled trials. These trials assessed the effects of 12 and 24 weeks of moderate versus high-intensity water aerobics on physical fitness and well-being in adults and older adults. A total of forty-one women participated. Of these, twenty-one women were randomly assigned to either the moderate-intensity group (MIG; n=11) or the high-intensity group (HIG; n=10) and engaged in 12 weeks of water aerobics. Furthermore, twenty participants completed 24 weeks of water aerobics, with 10 in the MIG and 10 in the HIG. Muscular endurance, explosive strength, body mass index (BMI), fat mass (FM), and general quality of life (QoL) were assessed at baseline and post-training. We used multiple linear regression to examine the relationship between the variables. The explosive strength of the upper limbs was influenced by the baseline values of explosive strength, muscular endurance, and BMI. The explosive strength of the lower limbs was related to the age of the participants, and the baseline values of FM, QoL, and muscular endurance in the lower limbs. The muscular endurance of the upper limbs was related to the participant's age and the initial values of muscular endurance of the lower limbs. The muscular endurance of the lower limbs was associated with both the intensity of the program and the baseline of muscular endurance in the lower limbs. The intensity of water aerobics plays a crucial role in improving lower limb muscular endurance, which in turn enhances functional capacity in both adults and older adults. The development of strength through water aerobics appears to be predominantly influenced by participants' initial levels of muscular endurance, their body composition, and their age. It is important to consider these variables when designing training programs.

Keywords: Water-based activities, muscular endurance, explosive strength, body composition, quality of life

Introduction

Muscular strength holds significant importance in the performance of activities of daily living and serves as a preventive measure against chronic diseases (Stump et al., 2006; Wolfe, 2006). Aging is normally linked to a decrease in force production capacity (Charlier et al., 2016; Frontera et al., 2000; Goodpaster et al., 2006; Janssen et al., 2000). This decline in strength with aging, known as dynapenia (Haynes et al., 2020), is characterized by the loss of muscle mass (Beaudart et al., 2017), leading to the loss of mobility and functional capacity (Visser et al., 2005; Yeung et al., 2019). As a result, there is an additional risk of falls and mortality rates (Ruiz et al., 2008; Yeung et al., 2019). Physical inactivity exacerbates these risks even further (English & Paddon-Jones, 2010). Water aerobics has become increasingly popular for addressing physical inactivity among healthy adults, older adults, and those with some limitations or chronic illnesses (Faíl et al., 2022; López et al., 2017; Kantyka et al., 2015; Raffaelli et al., 2016). The particularities of the aquatic environment, such as buoyance, drag forces, and lack of hypo gravity, along with the specificities of the modality, play a significant role in the positive results obtained (Borreani et al., 2014; Gusi et al., 2006; Meredith-Jones et al., 2011; Pöyhönen et al., 2002). In addition, the depth and temperature of the water, as well as some aquatic equipment (e.g., ankle cuffs or dumbbells) can also contribute to enhancing the improvements achieved (Aquatic Exercise Association, 2020; Barbosa et al., 2009; Gusi et al., 2006).

The literature has demonstrated that water aerobics can improve muscle strength after 12 (López et al., 2017; Moreira et al., 2018; Neiva et al., 2018) and 24 weeks (Colado et al., 2009; Novaes et al., 2014; Tsourlou et al., 2006). Some studies show that these gains are specific to certain muscle groups, with increases in strength observed either in the lower limbs (Neiva et al., 2018) or upper limbs (López et al., 2017; Moreira et al., 2018; Novaes et al., 2014). However, while some water aerobics programs monitor exercise intensity to maximize effectiveness, many do not, leading to variability in strength outcomes (Colado et al., 2009; Faíl et al., 2022; López et al., 2017; Moreira et al., 2018; Neiva et al., 2018; Novaes et al., 2014; Tsourlou et al., 2006). Importantly, there remains little information on the ideal program duration and intensity needed to achieve targeted muscle strength improvements.

Muscle strength is fundamental, particularly in aging populations, to counteract the effects of dynapenia, age-related muscle weakness, caused by the loss of muscle mass and the reductions in the muscle fiber, particularly fast-twitch fibers (Beaudart et al., 2017; Lexell et al., 1988; Porter et al., 1995). However, it remains unclear if dynapenia impacts the lower and upper limbs equally, particularly concerning explosive strength and muscular endurance. Additionally, there is limited insight into whether participants' baseline characteristics, such as age or pre-existing strength levels, influence the muscular strength gained from the water aerobics training program.

Based on the information provided, it is relevant to determine whether the muscle strength achieved through a water aerobics program is due to the program's intensity and duration, the age of the participants, or their baseline characteristics. To our knowledge, no studies have investigated these factors in the context of water aerobics among adults and older adults. Therefore, the primary purpose of the study was to analyse whether the muscular strength of adults and older adults after participating in water aerobics for 12 and 24 weeks, is influenced by the following factors: i) the duration and intensity of the program; ii) the age of participants; iii) and the initial values of muscle strength, body composition and quality of life (QoL). We hypothesized that program intensity, participant age, and initial muscle strength would significantly influence strength gains. We also hypothesized that duration and baseline values of body composition and QoL would not relate to the muscle strength values obtained.

Methods

Study design

This research constitutes a secondary analysis of prospective data acquired from two pragmatic randomized controlled trials. These trials compare the impact of 12 and 24 weeks of moderate versus high-intensity water aerobics on muscle strength, body composition, lipid profile, BP, and QoL in adults and older adults (Faíl et al., 2024a; Faíl et al., 2024b). By including the data from these two articles, our study aims to investigate whether the age, duration (12 and 24 weeks), and intensity (moderate and high) of a water aerobics program, as well as the initial values (baseline) of physical fitness, anthropometrics, and well-being in adults and older adults, have a relationship and influence the results in muscle strength obtained after each water aerobics program.

Participants and Intervention

Twenty-one women were randomly allocated to either the moderate-intensity group (MIG; n=11) or the high-intensity group (HIG; n=10) and participated in 12 weeks of water aerobics (Faíl et al., 2024b). Additionally, twenty women completed 24 weeks of water aerobics - 10 in MIG and 10 in HIG (Faíl et al., 2024a). The program schedule consisted of two sessions per week, with each session lasting 45 minutes. Information about study participants and interventions that is missing is present in these two studies.

Outcomes measures

The primary purpose of this study was to investigate whether various factors such as baseline muscle strength, body composition, QoL, participants' age, and the duration and intensity of water aerobics programs, have any association with changes in muscle strength among adults and older adults following participation in water aerobics. For this, the following variables were assessed one week before the programs began (pre) and one week after they ended (post): i) muscle strength - a) explosive strength, with the evaluation of the countermovement jump (CMJ), and the 3 kg medicine ball throw (MBT); b) muscular endurance, assessing the chair stand test (CST), and the arm curl test (AC); ii) anthropometry, evaluating the body mass index (BMI), and fat mass percentage (FM); iii) and general QoL.

In the present analysis, certain variables from studies of Faíl et al. (2024a) and Faíl et al. (2024b) were not included as it was not relevant to predict muscle strength based on them. The excluded variables were: lipid profile (triglycerides and total cholesterol), systolic and diastolic blood pressure, resting heart rate, body mass, fat-free mass, and the subdomains of QoL. All other methodological information regarding the assessment of each variable can be found in these two studies.

Statistical analysis

Statistical Package for Social Sciences (IBM SPSS Statistics for Windows, version 28.0, IBM Corp., Armonk, NY, USA) was used to perform the statistical analysis. Statistical significance was set at $p \leq 0.05$. Initially, standard statistical methods were applied to calculate means and standard deviations, providing a descriptive summary of the data. After ensuring that the assumptions underlying the analysis of residues were not violated (normality, homoscedasticity and independence), a multiple linear regression analysis was conducted to evaluate the influence of the independent variables on the post-values of muscle strength variables (MBT_{post}, AC_{post}, CMJ_{post}, and CST_{post}). The following variables were considered as independent variables: age, program duration (12 and 24 weeks) and intensity (moderate and high), as well as baseline values of muscle strength, body composition, and general QoL. The normality was verified by the Kolmogorov-Smirnov test. To assess the homogeneity of variances, a scatterplot of standardized predicted values against studentized residuals was generated. Independence was evaluated using the Durbin-Watson statistic. No evidence of collinearity or multicollinearity was detected among the independent variables. It was considered the Backward method for variable selection. The adjusted R^2 was utilized to assess the quality of the model fit. Its interpretation as an effect size measure was based on the following criteria: 0.02–0.13 small, 0.13–0.26 medium, and >0.26 large effect size (Cohen, 1988).

Results

A descriptive summary of the baseline data for the two water aerobics programs (12 and 24 weeks) is provided in Table 1.

Table 1. Characteristics of participants at baseline in the 12 and 24-week water aerobics studies (mean ± SD).

Variable	**12 weeks**		**24 weeks**	
	MIG (n = 11)	**HIG (n = 10)**	**MIG (n = 10)**	**HIG (n = 10)**
Age [years]	63.18 ± 8.64	67.40 ± 10.09	65.5 ± 8.33	68.7 ± 9.94
Height [m]	1.58 ± 0.07	1.56 ± 0.06	159.1 ± 5.76	159.0 ± 5.75
Body mass [kg]	69.65 ± 10.44	75.94 ± 17.66	70.46 ± 11.02	77.46 ± 17.89
BMI [kg/m^2]	28.16 ± 4.76	31.39 ± 7.63	29.03 ± 4.90	32.02 ± 7.66
Fat mass [%]	38.99 ± 5.68	41.53 ± 6.34	39.72 ± 5.99	42.36 ± 6.35
CMJ [cm]	6.56 ± 3.49	5.34 ± 3.57	6.93 ± 3.58	5.44 ± 3.57
MBT [cm]	2.29 ± 0.32	2.12 ± 0.42	2.28 ± 0.29	2.16 ± 0.42
CST [reps]	14.00 ± 2.93	15.80 ± 5.94	14.69 ± 2.77	16.12 ± 5.96
Arm Curl [reps]	19.18 ± 2.99	22.10 ± 7.46	19.89 ± 2.97	22.54 ± 7.48
QoL-General	62.50 ± 13.69	55.00 ± 19.72	62.45 ± 13.58	56.10 ± 19.91

BMI Body Mass Index, *CMJ* Countermovement Jump, *CST* Chair Stand Test, *HIG* High Intensity Group, *MBT* Medicine Ball Throw, *MIG* Moderate Intensity Group, *QoL* Quality of Life, *SD* Standard Deviation

In Table 2, we present the estimated regression coefficients from linear regression models, including only the independent variables that significantly influenced the post-values of muscle strength. Through this analysis, we found a significant positive relationship between MBT_{post} and both MBT_{pre} and AC_{pre}. Specifically, higher MBT_{pre} and AC_{pre} values corresponded to greater MBT_{post}. Additionally, we found a significant negative relationship between MBT_{post} and BMI_{pre}, with lower BMI_{pre} values linked to higher MBT_{post}.

A significantly positive association was observed between CMJ_{post} and both QoL_{pre} and CST_{pre}. Higher QoL_{pre} and CST_{pre} values were associated with higher CMJ_{post} values. Furthermore, there was a negative and significant association between CMJ_{post} and age as well as FM_{pre}. The lower the age and the FM_{pre} value, the higher the CMJ_{post}.

In the AC_{post} model, there was a significant positive association with age and CST_{pre}. The AC_{post} was more elevated in older participants and those with higher CST_{pre} values.

In the CST_{post} model, we observed a significant positive relationship with intensity and CST_{pre}. This suggests higher values on CST_{post} for those who perform better on CST_{pre}. Moreover, it is projected that CST_{post} shows better results after engaging in high-intensity water aerobics compared to the same program at moderate intensity.

Table 2. Estimated regression coefficients from linear regression models for post-values of muscle strength.

Dependent Variable	**Independent Variables***	**Coefficient (95% CI)**	**p-value**	**R_a^2**	**ANOVA (p-value)**
MBT_{post} [cm]	Constant	0.394 (-0.084 to 0.872)	0.103	0.805	<0.001
	BMI_{pre}	-0.019 (-0.029 to -0.009)	<0.001		
	MBT_{pre}	0.940 (0.749 to 1.130)	<0.001		
	AC_{pre}	0.019 (0.006 to 0.031)	0.005		
CMJ_{post} [cm]	Constant	17.049 (9.891 to 24.208)	<0.001	0.682	<0.001
	Age	-0.145 (-0.213 to -0.078)	<0.001		
	Fat $Mass_{pre}$	-0.210 (-0.328 to -0.092)	<0.001		
	QoL_{pre}	0.051 (0.012 to 0.091)	0.012		
	CST_{pre}	0.291 (0.136 to 0.445)	<0.001		
AC_{post} [reps]	Constant	-1.578 (-8.923 to 5.767)	0.666	0.735	<0.001
	Age	0.117 (0.024 to 0.210)	0.015		
	CST_{pre}	0.449 (0.125 to 0.773)	0.008		
CST_{post} [reps]	Constant	5.071 (2.484 to 7.659)	<0.001	0.703	<0.001
	Intensity (MIG_HIG)	1.685 (0.190 to 3.179)	0.028		
	CST_{pre}	0.743 (0.576 to 0.911)	<0.001		

$p<0.05$; * Only significant variables were reported; *AC* Arm Curl; *BMI* Body Mass Index; *CI* Confident Interval; *CMJ* Countermovement Jump; *CST* Chair Stand Test; *HIG* High Intensity Group; *MBT* Medicine Ball Throw; *MIG* Moderate Intensity Group; *post* variable evaluated after the program ends; *pre* variable evaluated before starting the program; *QoL* General Quality of Life; *reps* Repetitions; R_a^2 adjusted R square

Linear regression analysis indicated that the significant independent variables explained 80.5% of the variance in MBT_{post}, 73.5% in AC_{post}, 68.2% in CMJ_{post}, and 70.3% in CST_{post}. Additionally, we obtained the following regression equations to each muscle strength, highlighting how the significant explanatory variables influence them (Table 3).

Table 3. Regression equations for each muscle strength post-value.

Variables	General model equations	MIG	HIG
MBT_{post} [cm]	$0.394 - 0.019 \times BMI_{pre} + 0.940 \times MBT_{pre} + 0.019 \times AC_{pre}$		
AC_{post} [reps]	$-1.578 + 0.117 \times Age + 0.449 \times CST_{pre} + 0.512 \times AC_{pre}$		
CMJ_{post} [cm]	$17.049 - 0.145 \times Age - 0.210 \times FM_{pre} + 0.051 \times QoL_{pre} + 0.291 \times CST_{pre}$		
CST_{post} [reps]		$5.071 + 0.743 \times CST_{pre}$	$(5.071 + 1.685) + 0.743 \times CST_{pre}$

AC Arm Curl; *BMI* Body Mass Index; *CMJ* Countermovement Jump; *CST* Chair Stand Test; *FM* Fat Mass; *HIG* High Intensity Group; *MBT* Medicine Ball Throw; *MIG* Moderate Intensity Group; *post* variable evaluated after the program ends; *pre* variable evaluated before starting the program; *QoL* Quality of Life; *reps* Repetitions

Discussion

The current study aimed to determine whether the muscle strength of upper and lower limbs in water aerobics practitioners is associated with the intensity and duration of the program, the participants' age, and their baseline levels of muscle strength, body composition, and QoL. The main findings were: i) the explosive strength of the upper limbs was influenced by the initial values of explosive strength and muscular endurance in the upper limbs, as well as the BMI; ii) the explosive strength of the lower limbs showed a significant relationship with the age of the participants, as well as the initial values of FM, QoL, and muscular endurance in the lower limbs; iii) there was a relationship between the muscular endurance of the upper limbs and the participant's age, and with the initial value of muscular endurance in the lower limbs; and iv) the muscular endurance of the lower limbs was significantly impacted by both the intensity of the program and the initial value of muscular endurance in the lower limbs. The results partially support our first hypothesis, showing that the program intensity, participant's age, and some baseline muscle strength values would influence most muscle strength values after water aerobics. Our second hypothesis was not fully supported, as part of the explosive strength was related to body composition and QoL. Despite this, the 12 weeks or 24 weeks duration did not show relationship with muscular strength, agreeing with the second hypothesis.

The explosive strength of the upper limbs was influenced by the baseline values of the upper limbs' explosive strength and muscular endurance, as well as by the BMI. Specifically, an increase in upper explosive strength was expected when the initial values of the upper limbs' explosive strength and muscular endurance were higher. A previous study emphasized the significance of muscular strength and power in achieving good performance in specific muscular endurance tests (Naclerio et al., 2009). These findings differ from ours; however, both studies emphasize the importance of various forms of strength production in participating in diverse physical activities (Baker, 2001a; Baker, 2001b; Naclerio et al., 2009). Interestingly, a lower baseline BMI was linked to greater upper explosive strength at the end of the water aerobics intervention. Overweight or obese individuals often have less ability to perform explosive movements like throwing than those within a normal weight range (Rauner et al., 2013). Excessive body mass can cause additional burden, restricting some movements and decreasing performance (Ding & Jiang, 2020). Even in water aerobics, where water reduces the effect of body weight on the joints, it is probably for obese individuals still face greater difficulty compared to those with a normal weight, and resulting in lower velocities while exercising. Therefore, when planning a water aerobics session aimed at improving upper explosive strength, it is essential to select exercises suitable to the individual's body composition as well as their muscular endurance and explosive strength in the lower limbs.

The age and baseline values of FM, QoL, and muscular endurance of the lower limbs were good predictors of lower limbs' explosive strength performance. Lower age and initial FM values were associated with higher values of explosive strength in the lower limbs after intervention. Several studies have found impaired physical function when the FM percentage was higher (Bouchard et al., 2007; Sternfeld et al., 2002). FM is particularly important in vertical jump performance, with negative relationships reported between FM and jump quality (Acar & Eler, 2019; Sari et al., 2021). This occurs because the presence of FM adds weight to movements without contributing to force production and may even impair it due to reductions in muscle contraction (Orssatto et al., 2020). Aging also leads to declines in explosive strength (Häkkinen et al., 1998; Perroni et al., 2015). This phenomenon can be attributed to several factors, including a decrease in the size and number of type II muscle fibers or a tendency for adiposity to increase with advancing age (Freire, 2024; Gallagher et al., 2000; Nilwik et al., 2013; Ohkawa et al., 2005). As we age, the increase in body fat can make movements more challenging, while the reduction in type II fibers negatively impacts explosive strength performance. This helps explain the negative association observed in our study between these factors and the explosive strength of the lower limbs. Furthermore, increases in explosive strength of the lower limbs were estimated with higher initial values in QoL and muscular endurance of the lower limbs. Usually, a higher QoL is linked to improved mobility and the ability to perform activities of daily living in older adults (Groessl et al., 2007). Thus, greater independence in performing different activities is expected to result in better functional capacity, including improved muscular endurance, higher QoL, and consequently, increased rates of generating explosive strength in the lower limbs.

Curiously, the baseline values of lower limb muscular endurance and age influenced upper muscular endurance. Higher baseline values of lower limb muscular endurance were associated with better results in upper muscular endurance. Indeed, several studies indicate a strong relation between lower limb muscle strength and whole-body muscle strength (Alves et al., 2022; Coelho-Júnior et al., 2023; Pereira et al., 2024). Increased lower limb strength is generally associated with enhancements in balance (Cho et al., 2012). This allows for improved movement with a greater range of motion in both lower and upper limbs. Additionally, a reduced imbalance in water environments enhances the capacity to perform exercises at higher speeds, regardless of whether they engage the lower or upper limbs. Given that speed relates directly to drag forces, an increase in velocity exposes individuals to heightened drag forces, which require a greater expenditure of metabolic energy to counteract this external resistance (Barbosa et al., 2009). When exercises are conducted at increased speeds, particularly those that combine movements of both lower and upper extremities, there is a concomitant rise in mechanical work (Barbosa et al., 2009; Costa et al., 2008; Darby & Yaeckle, 2000; Yu et al., 1994), leading to enhanced training outcomes, including upper muscular endurance. Typically, strength decreases with advancing age due to a loss of muscle volume (muscular factor) and reduced neural impulse to activate muscles (neural factor) (Dalton et al., 2010; Granacher et al., 2012). However, our study found that older individuals exhibited better upper-body muscular endurance results after participating in water aerobics. This finding may be attributed to the lower levels of physical and muscular conditioning observed in the oldest individuals in our sample at the beginning of the program. Commonly, inexperienced individuals with lower physical conditioning experience a greater rate of improvement in muscular strength compared to those with more training experience (Peterson et al., 2005). This phenomenon can be explained by neural adaptations and increased motor unit activation (Behm, 1995; Staron et al., 1994).

The lower limb muscular endurance performance was influenced by the baseline value of lower limb muscular endurance and the program's intensity. The muscular endurance of the lower limbs was greater at the end of the program when the baseline muscular endurance was also higher. This finding was consistent with earlier results from this study, where higher baseline values of lower limb muscular endurance contributed to improved performance in both lower limb explosive strength and upper body muscular endurance. This highlights the importance of muscular endurance for adults and older women engaged in water aerobics. The faster loss of type II fibers, responsible for explosive movements, due to aging may explain the greater influence of baseline muscular endurance on the results achieved in both muscular endurance and explosive strength after performing water aerobics (Brooks & Faulkner, 1994; Faulkner et al., 2008; Frontera et al., 1991; Goodpaster et al., 2006).

Importantly, intensity played a significant role in the muscular endurance of lower limbs, with HIG being associated with better results compared to MIG. The evaluation used for muscular endurance of lower limbs (CST) is usually associated with muscle performance, functional fitness, flexibility, and aerobic endurance in older adults (Bodilsen et al., 2015; Jones et al., 1999). Therefore, these results could be associated with the better functional capacity of older adults (Cruz-Montecinos et al., 2024), gait speed, balance (Yee et al., 2021), and the ability to perform activities of daily living independently (Yamada et al., 2012). Lower limb strength serves as a strong predictor of various adverse health-related events in older adults, such as mobility issues (Zoico et al., 2004), frailty (Xue, 2011), fall risk (Berry & Miller, 2008), and QoL (Bye et al., 2017). Therefore, water aerobics intensity plays a crucial role in enhancing muscular endurance in the lower limbs, which in turn improves the functional capacity of adults and older adults while reducing the likelihood of adverse events occurring.

The authors initially hypothesized that exercise intensity would affect all muscular strength variables; however, this was not observed in the muscular endurance of the upper limbs or explosive strength. A strong influence of intensity on all muscle strength variables was expected since higher intensities in water aerobics are typically associated with quicker exercise execution, which is critical for improving muscle strength levels (Torres-Ronda & Alcázar, 2014). It is possible that the specific exercises and training methods used can also play a significant role in the upper limb muscular endurance and explosive strength. For example, a water-based program that focuses on sets of bounds, hops, and jumps performed at high speeds has shown to yield significant strength improvements (Robinson et al., 2004). Therefore, it is recommended to incorporate high-speed exercises, such as jumps, into water aerobics, particularly when the primary goal is to enhance explosive strength in both the upper and lower limbs, as well as the muscular endurance of the upper limbs.

Conclusion

The current study found that initial explosive strength and muscular endurance in the upper limbs, as well as BMI, influenced the explosive strength of the upper limbs. Additionally, participants' age, along with baseline values of FM, QoL, and muscular endurance in the lower limbs, were associated with the explosive strength of the lower limbs. Moreover, the participants' age and their initial muscular endurance in the lower limbs were related to the muscular endurance of the upper limbs. Both the intensity of the program and the initial muscular endurance in the lower limbs were linked to the improvements in muscular endurance of the lower limbs following water aerobics. Overall, the intensity of water aerobics plays a crucial role in enhancing lower limb muscular endurance, which ultimately leads to improved functional capacity in both adults and older adults. Furthermore, the development of muscle strength through water aerobics is significantly influenced by various individual factors. The initial levels of muscular endurance that participants possess before starting the water aerobics program can determine their strength progress and adaptation to the workouts. The participants' initial body composition and age are also important factors that affect the strength outcomes of water aerobics training. Considering these variables when designing training programs is essential for maximizing the benefits of water aerobics and ensuring safe and effective workouts for all participants involved.

Study 5. Association between duration, intensity, age of participants, and the health-related outcomes after 12 and 24 weeks of water aerobics

Abstract

This study aimed to analyse the relationship between the blood pressure (BP) and lipid profile outcomes derived from a water aerobics program and factors such as the program's intensity and duration, the participant's age, and their baseline levels of BP, lipid profile, anthropometric, and quality of life (QoL). This study investigated data from two randomized controlled trials that examined the impact of 12 and 24 weeks of moderate versus high-intensity water aerobics on physical fitness, cardiovascular health, and well-being in adults and older adults. In total, forty-one women participated. Of those, twenty-one women were randomly assigned to either the moderate-intensity group (MIG; n = 11) or the high-intensity group (HIG; n = 10) and performed 12 weeks of water aerobics. Additionally, twenty participants completed 24 weeks of water aerobics (10 in MIG and 10 in HIG). The following variables were evaluated before and after each program: systolic BP, diastolic BP, triglycerides, total cholesterol, body mass index (BMI), fat mass percentage (FM), and QoL. The baseline levels of systolic BP and total cholesterol exerted a significant influence on systolic BP. Diastolic BP obtained after programs demonstrated a relationship with initial diastolic BP, total cholesterol, and the program's duration. Triglycerides levels achieved after intervention were substantially associated with the program's intensity, as well as with the initial values of triglycerides, diastolic and systolic BP. Program intensity, along with baseline levels of total cholesterol and BMI were significantly related to the final results of total cholesterol. Overall, the findings indicated that i) baseline values of total cholesterol influence the BP responses observed after a water aerobics program; ii) water aerobics intensity is relevant for determining lipid profile improvement, and the duration of the water aerobics program is significant for diastolic BP.

Keywords: Water-based activities, blood pressure, cholesterol total, triglycerides, quality of life

Introduction

Elevated blood pressure (BP) and abnormal lipid profile levels are known as significant risk factors for the onset of cardiovascular diseases (Arima et al., 2011), particularly coronary artery disease, stroke, and heart failure (Whelton et al., 2018). Studies have shown that women over 50 years of age are more prone to high BP (Kearney et al., 2005; Coylewright et al., 2008; Reckelhoff, 2001). Particularly, in Portugal, approximately 26% of adults aged 30 to 79 years are estimated to have hypertension (World Health Organization, 2023). Furthermore, women typically experience a significant increase in total cholesterol (TC) levels upon the onset of menopause (Matthews et al., 2009). However, it is well-documented that a reduction of ~10 mmHg in systolic BP can reduce the risk of developing major cardiovascular disease by 20%, coronary artery disease by 17%, stroke by 27%, heart failure by 28%, and mortality risk by 13% (Ettehad et al., 2016). Lowering TC and triglyceride (TG) levels also demonstrates favorable effects in mitigating these diseases (Magalhães, 2017).

Given these significant cardiovascular risks, particularly among older individuals and women, effective strategies to lower cardiovascular risk factors, i.e., improving BP and lipid profiles, are crucial. One such strategy is physical exercise, which has been shown to have a positive impact on both BP and lipid levels. Different physical exercise programs have been used to reduce the values of these risk factors. Studies have indicated that both normotensive and hypertensive individuals experience a reduction in BP following a single session of aerobic or resistance exercise (Bermudes et al., 2004; Melo et al., 2006; Pescatello et al., 2004; Pescatello & Kulikowich, 2001). The extent and duration of this decrease depend on the type and intensity of the exercise performed (Quinn, 2000; Wallace et al., 1997), with the most significant and lasting effects observed in individuals with higher baseline BP (Cardoso et al., 2010). Furthermore, structured and long-term exercise programs have been shown to positively influence both BP and lipid profiles (Whelton et al., 2018).

In the search for effective alternatives to traditional land-based exercises, water-based activities, such as water aerobics, have gained increasing attention due to their ability to reduce cardiovascular risk factors (Cunha et al., 2016; Moura et al., 2024). The unique properties of water, such as drag forces, hydrostatic pressure, buoyancy, viscosity, and temperature, create distinct physiological responses compared to land-based exercises, enhancing the potential benefits of cardiovascular health (Torres-Ronda & Alcázar, 2014). Specifically, water's buoyancy minimizes impact on the limbs, rendering it a safe option for individuals with lower fitness levels or lower limb limitations or injuries (Barbosa et al., 2007). Immersion in water changes hydrostatic pressure, causing blood to redistribute to the thoracic cavities, which increases stroke volume and cardiac output (Cider et al., 2005; Sik Park et al., 1999). Additionally, exerting against water resistance amplifies the workload (through drag forces). Increased heat exchange between the body and water (Barbosa et al., 2007) can also aid in regulating body temperature during exercise.

These factors have demonstrated some ambiguity regarding the effect of water aerobics on BP and lipid profile. Several studies have reported divergent results, with some programs leading to improvements in systolic BP (Neiva et al., 2018; Piotrowska-Całka, 2010) and diastolic BP (Green, 1989; Sobczak et al., 2023), while others show no significant changes in systolic BP (Green, 1989; Moura et al., 2020; Sobczak et al., 2023) and diastolic BP (Moura et al., 2020; Neiva et al., 2018; Piotrowska-Całka, 2010). Certain programs have shown improvements in TC and TG levels (Kasprzak & Pilaczyńska-Szcześniak, 2014; Moura et al., 2020), while others have not yielded similar results (Kantyka et al., 2015; Neiva et al., 2018; Sobczak et al., 2023). It is important to note that most of these programs lasted between 12 and 24 weeks and were conducted at moderate intensity. Although there is literature on the effects of water aerobics on BP and lipid profile, there remains a significant gap in research regarding the impacts of different exercise intensities. Furthermore, it is crucial to identify which specific variables contribute most effectively to the outcomes observed in water aerobics conducted at varying intensities and durations.

Therefore, it seems to be essential to determine whether participants' baseline characteristics, such as their pre-existing BP and lipid profile levels, influence the changes in these variables resulting from the water aerobics training program. Additionally, we must consider whether factors like participants' age or the intensity and duration of the exercise programs have a more significant impact on cardiovascular health outcomes. In this context, the current study aimed to investigate whether the BP and lipid profile outcomes of adults and older adults participating in water aerobics are influenced by: i) the duration of the program (12 or 24 weeks) and its intensity (moderate or high); ii) the age of the participants; and iii) the baseline values of BP, lipid profile, body composition, and quality of life (QoL). The authors hypothesized that the BP and lipid profile after water aerobics would be influenced by the program's intensity, duration, and the participants' age. It was also hypothesized that most baseline variables would affect BP and lipid profile after the water aerobics programs.

Methods

Study design

This study encompasses the analysis of existing data derived from two pragmatic randomized controlled trials. These trials evaluated the impact of 12 and 24 weeks of moderate and high-intensity water aerobics on muscle strength, anthropometric, BP, lipid profile, and QoL in adults and older adults(Faíl et al., 2024a; Faíl et al., 2024b) Using data from these two studies, our research aims to determine if factors such as baseline cardiovascular health, body measurements, overall well-being, participants' age, and the duration and intensity of water aerobics programs are related to changes in cardiovascular health among adults and older adults after participating in water aerobics.

Participants and Intervention

Twenty-one women were randomly assigned to either the moderate-intensity group (MIG; n=11) or the high-intensity group (HIG; n=10) and underwent 12 weeks of water aerobics (Faíl et al., 2024b). Furthermore, twenty women completed 24 weeks of water aerobics, with 10 participants in MIG and 10 in HIG (Faíl et al., 2024a). The exercise program comprised two 45-minute sessions per week. Detailed information about the study participants and the interventions that are lacking can be found in these two studies.

Outcomes measures

Our research primarily aimed to explore the potential relationship between baseline BP, lipid profile, body composition, QoL, age, duration, and intensity of water aerobics programs, and the changes in BP and lipid profile in adults and older adults after participating in water aerobics. We evaluated the following variables one week before the programs started (pre) and one week after they ended (post): i) systolic BP and diastolic BP; ii) lipid profile, including TC and TG; iii) body composition, such as body mass index (BMI) and fat mass percentage (FM); and iv) general QoL.

In our current analysis, we excluded certain variables from studies of Faíl et al. (2024a) and Faíl et al. (2024b) as they were not pertinent to predicting cardiovascular health. The excluded variables were: explosive strength (countermovement jump and medicine ball throw), muscular endurance (chair stand test and arm curl test), resting heart rate, body mass, fat-free mass, and the subdomains of QoL. Additional methodological details about the assessment of each variable can be found in these two studies.

Statistical analysis

The statistical analysis was conducted using IBM SPSS Statistics for Windows, version 28.0, by IBM Corp. in Armonk, NY, USA. A significance level of $p \leq 0.05$ was set for the analysis. Standard statistical methods were initially used to calculate means and standard deviations, supplying a descriptive summary of the data. Following this, a rigorous evaluation was conducted to ensure that the assumptions about the analysis of residuals - namely normality, homoscedasticity, and independence - were not violated. A multiple linear regression analysis was performed to assess the influence of independent variables on the post-intervention values of BP and lipid profile variables, specifically systolic BP_{post}, diastolic BP_{post}, TG_{post}, and TC_{post}. The independent variables under consideration included age, program duration (12 and 24 weeks), and intensity levels (moderate and high), along with baseline values of BP, lipid profile, body composition, and general QoL. The Kolmogorov-Smirnov test was used to verify normality. To evaluate the homogeneity of variances, a scatterplot depicting standardized predicted values versus studentized residuals was created. The Durbin-Watson statistic was utilized to assess independence. No signs of collinearity or multicollinearity were found among the independent variables. The Backward method was chosen for variable selection. The interpretation of the adjusted R^2 as a measure of effect size was based on the criteria established by Cohen (1988), which classifies effect sizes as follows: 0.02–0.13 indicates a small effect, 0.13–0.26 suggests a medium effect and greater than 0.26 represents a large effect size.

Results

Table 1 provides the baseline values of the descriptive summary for the two water aerobics programs.

Table 1. Characteristics of participants at baseline in the 12 and 24-week water aerobics studies (mean ± SD).

Variable	12 weeks		24 weeks	
	MIG (n = 11)	**HIG (n = 10)**	**MIG (n = 10)**	**HIG (n = 10)**
Age [years]	63.18 ± 8.64	67.40 ± 10.09	65.5 ± 8.33	68.7 ± 9.94
Height [m]	1.58 ± 0.07	1.56 ± 0.06	159.1 ± 5.76	159.0 ± 5.75
Body mass [kg]	69.65 ± 10.44	75.94 ± 17.66	70.46 ± 11.02	77.46 ± 17.89
BMI [kg/m^2]	28.16 ± 4.76	31.39 ± 7.63	29.03 ± 4.90	32.02 ± 7.66
Fat mass [%]	38.99 ± 5.68	41.53 ± 6.34	39.72 ± 5.99	42.36 ± 6.35
SBP [mmHg]	129.82 ± 20.36	138.10 ± 24.14	132.00 ± 21.27	140.90 ± 24.11
DBP [mmHg]	76.00 ± 12.30	81.90 ± 13.71	75.30 ± 10.47	83.50 ± 13.96
TG [mg/dl]	204.36 ± 59.53	187.70 ± 60.83	206.80 ± 62.52	191.50 ± 60.78
TC [mg/dl]	201.27 ± 30.34	210.90 ± 41.77	200.30 ± 27.00	215.10 ± 41.85
QoL-General	62.50 ± 13.69	55.00 ± 19.72	62.45 ± 13.58	56.10 ± 19.91

BMI Body Mass Index, *DBP* Diastolic Blood Pressure, *HIG* High Intensity Group, *MIG* Moderate Intensity Group, *QoL* Quality of Life; *SBP* Systolic Blood Pressure, *SD* Standard Deviation, *TC* Total Cholesterol, *TG* Triglycerides

The estimated regression coefficients from linear regression models are presented in Table 2, which exclusively encompasses the independent variables that influenced the post-values of BP and lipid profile. This analysis revealed a significantly positive relationship between systolic BP$_{post}$ and both systolic BP$_{pre}$ and TC$_{pre}$. Higher values of systolic BP$_{pre}$ and TC$_{pre}$ estimated higher values of systolic BP$_{post}$.

There was a significant association between diastolic BP$_{post}$ and both diastolic BP$_{pre}$ and TC$_{pre}$, suggesting that higher diastolic BP$_{pre}$ and TC$_{pre}$ levels are linked to more elevated diastolic BP$_{post}$ values. Additionally, there was a negative relationship between diastolic BP$_{post}$ and duration, indicating that diastolic BP$_{post}$ results are better (lower values) after 24 weeks of water aerobics compared to 12 weeks.

TG$_{post}$ was positively and significantly related to TG$_{pre}$ and diastolic BP$_{pre}$, showing higher TG$_{post}$ when TG$_{pre}$ and diastolic BP$_{pre}$ values are higher. On the other hand, there was a significant negative relationship between TG$_{post}$ and both systolic BP$_{pre}$ and intensity. Lower systolic BP$_{pre}$ values were associated with higher TG$_{post}$ values, and better TG$_{post}$ results were estimated when participants engaged in water aerobics at high intensity compared to moderate intensities.

A positive and significant association was found between TC$_{post}$ and both TC$_{pre}$ and BMI$_{pre}$. More precisely, higher TC$_{pre}$ and BMI$_{pre}$ values were linked to worse results (higher values) in TC$_{post}$. A negative association was also observed between TC$_{post}$ and intensity, with higher intensities estimating lower TC$_{post}$ values compared to water aerobics performed at moderate intensities.

Table 2. Estimated regression coefficients from linear regression models for post-values of blood pressure and lipid profile.

Dependent Variable	Independent Variables*	Coefficient (95% CI)	p-value	R_a^2	ANOVA (p-value)
SBP $_{post}$ [mmHg]	Constant	1.165 (-1.370 to 3.700)	0.358	0.728	<0.001
	SBP $_{pre}$	0.660 (0.523 to 0.798)	<0.001		
	TC $_{pre}$	0.015 (0.006 to 0.023)	0.001		
DBP $_{post}$ [mmHg]	Constant	1.729 -0.013 to 3.470)	0.052	0.570	<0.001
	Duration	-0.370 (-0.813 to 0.072)	0.098		
	DBP $_{pre}$	0.551 (0.367 to 0.734)	<0.001		
	TC $_{pre}$	0.007 (0.000 to 0.014)	0.037		
TG $_{post}$ [mg/dl]	Constant	27.879 (-30.102 to 85.860)	0.336	0.827	<0.001
	Intensity	-50.582 (-65.567 to -35.597)	<0.001		
	SBP $_{pre}$	-8.850 (-13.321 to -4.380)	<0.001		
	DBP $_{pre}$	20.699 (12.624 to 28.775)	<0.001		
	TG $_{pre}$	0.711 (0.584 to 0.839)	<0.001		
TC $_{post}$ [mg/dl]	Constant	9.393 (-53.948 to 72.734)	0.766	0.589	<0.001
	Intensity	-36.416 (-52.695 to -20.136)	<0.001		
	BMI $_{pre}$	1.486 (0.193 to 2.779)	0.025		
	TC $_{pre}$	0.802 (0.572 to 1.031)	<0.001		

$p<0.05$; * Only significant variables were reported; *BMI* Body Mass Index; *CI* Confident Interval; *DBP* Diastolic blood pressure; *HIG* High Intensity Group; *MIG* Moderate Intensity Group; *post* variable evaluated after the program ends; *pre* variable evaluated before starting the program; R_a^2 adjusted R square; *SBP* Systolic blood pressure; *TC* Total Cholesterol; *TG* Triglycerides

The results of the linear regression analysis indicate that the statistically significant independent variables explained 72.8% of the variability in systolic BP_{post}, 57% in diastolic BP_{post}, 82.7% in TG_{post}, and 58.9% in TC_{post}. This analysis also allowed us to develop linear regression equations for BP and lipid profile, demonstrating the influence of significant explanatory variables on these measures. The corresponding equations are presented in Table 3.

Table 3. Regression equations for each blood pressure and lipid profile post-value.

Variables	General model equations	MIG	HIG	12 weeks	24 weeks
SBP_{post} [mmHg]	$1.165 + 0.660 \times SBP_{pre} + 0.015 \times TC_{pre}$				
DBP_{post} [mmHg]				$1.729 + 0.551 \times DBP_{pre} + 0.007 \times TC_{pre}$	$(1.729 - 0.370) + 0.551 \times DBP_{pre} + 0.007 \times TC_{pre}$
$Trig_{post}$ [mg/dl]		$27.879 - 8.850 \times SBP_{pre} + 20.699 \times DBP_{pre} + 0.711 \times TG_{pre}$	$(27.879 - 50.582) - 8.850 \times SBP_{pre} + 20.699 \times DBP_{pre} + 0.711 \times TG_{pre}$		
TC_{post} [mg/dl]		$9.393 + 1.486 \times BMI_{pre} + 0.802 \times TC_{pre}$	$(9.393 - 36.416) + 1.486 \times BMI_{pre} + 0.802 \times TC_{pre}$		

BMI Body Mass Index; *DBP* Diastolic blood pressure; *HIG* High Intensity Group; *MIG* Moderate Intensity Group; *post* variable evaluated after the program ends; *pre* variable evaluated before starting the program; *SBP* Systolic blood pressure; *TC* Total Cholesterol; *TG* Triglycerides

Discussion

This research aimed to evaluate if the initial measurements of BP, lipid profile, body composition, QoL, participant's age, duration, and intensity of water aerobics have any relationships with the achieved BP and lipid profile after participating in these exercise regimens. The key results were as follows: i) systolic BP was significantly impacted by baseline levels of systolic BP and TC; ii) diastolic BP was significantly related to initial diastolic BP and TC, as well as the duration of the program; iii) TG levels were greatly influenced by the program's intensity, and by the initial values of TG, diastolic BP, and systolic BP; iv) TC was significantly associated with program intensity and the baseline of TC and BMI. The study hypotheses were partially confirmed. More specifically, the age of the participants did not affect any of the variables. However, the intensity and duration of the program influenced the lipid profile and diastolic BP, respectively.

Systolic and diastolic BP were positively influenced by baseline TC levels, indicating a relation between higher TC and increased BP. Previous research has revealed a positive correlation between TC and BP in normotensive and hypertensive populations (Munakata, 2015; Pereira et al., 2006). Elevated cholesterol levels in the bloodstream can contribute to plaque accumulation, resulting in arterial narrowing, exacerbation of atherosclerosis, and consequently an increase in BP (Humphrey et al., 2016; Kubozono et al., 2017). Furthermore, baseline BP values were positively associated with BP obtained after water aerobics, indicating that higher initial systolic BP and diastolic BP values were linked to higher systolic BP and diastolic BP values, respectively. Similarly, but applying only one training session, Taylor et al. (2010) found a correlation between baseline and final BP values. It would not be surprising to find no relationship in our study, as some researchers suggested that the relationship between pre- and post-exercise BP values tends to weaken when measurements are taken further apart in time (Bartko & Pettigrew, 1968; Taylor et al., 2010). Therefore, the significant relationship observed between initial and final BP values, despite variations in measurements at 12 and 24 weeks, could highlight the influence that initial values exert on BP after participating in a water aerobics program.

The only factor that influenced diastolic BP after the intervention was the duration of the exercise program. It was observed that 24 weeks of water aerobics yielded better results than 12 weeks. Exercise intensity did not affect BP, and the program's duration did not influence systolic BP. This aligns with Fagard (2001) statement that intensity, duration, and frequency only explain about 5% of the systolic BP variance and 1% of the exercise diastolic BP. It was expected that body composition would be a strong predictor of BP, given that obesity is widely acknowledged as a primary contributor to elevated BP (Kalil & Haynes, 2012). However, the analysis revealed no significant relationship between baseline BMI and FM with BP following water aerobics. As pointed out by Wakabayashi (2004), the relationship between BMI and BP may differ according to the ethnicity of the population studied, with variations observed across different countries and age demographics (Deurenberg-Yap et al., 2001; Henriksson et al., 2002; Lear et al., 2003). For instance, research conducted by He et al. (1994) and Matsumura et al. (2001) demonstrated a significant relationship between BMI and BP among older Chinese and Japanese individuals, respectively. In contrast, Chen et al. (1995) and Wakabayashi, (2004) noted a more pronounced relationship between these variables in younger individuals compared to older adults. Additionally, in the current study, the absence of a relation between body composition and BP may be attributed to increased variability in BP among older adults. This variability is likely influenced by alterations in cardiovascular neural control mechanisms, as suggested by Mancia et al. (1995).

The intensity of water aerobics and baseline levels of TG, diastolic BP, and systolic BP were found to be good predictors of TG levels after completing the program. HIG estimated better results in TG levels compared to MIG. Cox et al. (2001) emphasized that the type of exercise, its intensity, frequency, and session/program duration, significantly influence the outcomes observed in lipid profiles. In the present study, we focused specifically on examining the relationship between lipid profiles and the exercise program's duration and intensity. Interestingly, regarding TG, only the exercise intensity exhibited a statistically significant association. Additionally, high baseline values of TG and diastolic BP predicted higher TG after water aerobics. Several studies indicated that elevated TG levels, particularly when accompanied by low HDL cholesterol, are a more significant predictor of coronary artery disease than BP (Jeppesen et al., 2000). On the other hand, other researchers emphasize the importance of managing BP in individuals with high TG to mitigate the risk of stroke (Collins et al., 1990). Strangely, in our study, lower baseline values in systolic BP were associated with higher post-exercise TG levels. This finding presents considerable challenges in explanation. Nevertheless, regardless of the primary risk factor associated with cardiovascular diseases, the optimal strategy is to manage BP and TG concurrently (Jeppesen et al., 2000) rather than focusing solely on one risk factor. Although the current study indicates that the intensity of exercises primarily affects TG, we also previously established a relation between the duration of the exercise program and BP. Therefore, performing high-intensity water aerobics over 24 weeks may effectively contribute to the management of both risk factors associated with these diseases.

Higher initial values of TC and BMI were associated with higher TC levels after participating in water aerobics. Several studies support this relationship between BMI and TC (Alexander, 2001; Brown et al., 2000). Likely, lower BMI values will also be associated with reduced TC levels. These findings are significant, as elevated body weight is recognized as a major predictor of cardiovascular diseases (Sobczak et al., 2023). In addition, the level of TC was influenced by the intensity of the exercise program. In particular, engaging in HIG estimated better TC compared to MIG. Marrugat et al. (1996) conducted a comparative analysis of various activities with differing intensities, revealing that higher intensity levels corresponded to more significant reductions in TC. Consequently, engaging in water aerobics at elevated intensities, while monitoring certain anthropometric parameters, appears to be critical for managing TC and, by extension, mitigating the risk of cardiovascular diseases.

Advancing age is generally associated with negative effects on BP and lipid profiles (Assman et al., 1998). Specifically, both BP and the prevalence of hypertension typically increase with age (Burt et al., 1995; Vasan et al., 2002; Whelton, 1994). TC and TG levels also exhibit similar trends (Marhoum et al., 2013; Wakabayashi, 2012). Consequently, the authors postulated that the age of the participants would significantly influence BP and lipid profiles following water aerobics interventions. Notably, the results indicated that there was no influence. The absence of a significant relationship between age and the studied variables may be attributed to the fact that our research exclusively involved women. Certain variables, such as TC, exhibit different trends with age when comparing women and men (Wenger, 1999). Research has raised questions about whether aging is the only factor contributing to the rise in these variables. It suggests that changes in body composition associated with aging, as well as shifts in lifestyle, may also play a significant role (Gostynski et al., 2004). Therefore, given the lack of relation between age and BP and lipid profiles, it is plausible that factors such as exercise performed and dietary habits (which were not monitored) may have exerted a more significant influence.

Conclusion

The present study demonstrates that baseline systolic BP and TC values significantly influenced systolic BP outcomes. Additionally, the duration of the water aerobics program, along with initial diastolic BP and TC values, affected diastolic BP post-training values. Program intensity, as well as baseline TG and BP (diastolic and systolic), had a significant impact on post-TG levels. Furthermore, TC levels were associated with both program intensity and initial TC and BMI values. Overall, baseline TC proved to be significant in the BP responses observed after the water aerobics sessions, while the program's intensity played a crucial role in modifying lipid profiles. The duration of the water aerobics program was only relevant for diastolic BP. The results of this study offer significant insights for water aerobics instructors, equipping them with a better understanding of the specific variables to prioritize when training adult and older women. By focusing on these key factors, instructors can design programs more effectively to enhance cardiovascular health, particularly in lowering blood pressure and improving lipid profiles. This knowledge allows for tailored approaches that address the unique needs of this demographic, ultimately leading to more successful health outcomes in their water aerobics sessions.

Chapter 4. General Discussion

The main purpose of the current thesis was to evaluate the effects of different intensities and durations of water aerobics programs on health-related variables in adults and older adults. Specifically, the changes in muscle strength, body composition, blood pressure (BP), lipid profile, and quality of life (QoL) induced by these programs were analyzed. First, to provide a comprehensive understanding of the existing literature, Study 1 conducted a systematic review with meta-analysis that evaluated the effects of aquatic exercise on the health status and physical fitness of healthy adults and adults with chronic diseases. Subsequently, the remaining experimental studies were conducted to address the overall purpose of the thesis. Studies 2 and 3 compared the effects of moderate and high intensity water aerobics on muscle strength, anthropometric measures, lipid profile, BP, and QoL in adults and older adults. In the second study, the interventions were implemented over 12 weeks, while the third study was extended to 24 weeks. Finally, the following studies provided a detailed analysis of the factors contributing to the observed outcomes of these programs. Study 4 examined the potential relationship between muscle strength achieved through water aerobics programs and several variables, including program intensity and duration, age of participants, and baseline assessments of muscle strength, body composition, and overall QoL. Study 5 examined the associations between several factors - including baseline BP, lipid profile, body composition, QoL, age of participants, and the duration and intensity of water aerobics programs - and subsequent changes in BP and lipid profile after participation in water aerobics.

The first study showed that aquatic exercise significantly improved strength, balance, and cardiorespiratory fitness in healthy adults. These findings underscore the efficacy of such an exercise program when performed for a minimum duration of 12 weeks, with sessions occurring 2 to 3 times per week and lasting between 46 and 65 minutes each. In adults with chronic diseases, although specific adaptations may vary depending on the disease, it can be stated that water-based programs primarily improve balance, QoL, strength, pain, and gait. These benefits typically occurred after 8 to 16 weeks of exercise. Despite these findings, only a limited number of studies examined the effects of their programs using water aerobics (Andrade et al., 2020; Graef et al., 2010; Moreira et al., 2017; Neiva et al., 2018; López et al., 2017). Furthermore, several studies did not report or monitor exercise intensity (Aidar et al., 2018; Arnold & Faulkner, 2010; Ayán & Cancela, 2012; Cruz, 2017; Matsumoto et al., 2016; Oliveira et al., 2014; Pires et al., 2015; Vale et al., 2020; Vieira et al., 2015; Suomi & Lindauer, 1997; Zhu et al., 2018), indicating a significant gap that needs to be addressed. To fill this gap, it has been suggested that more programs should be conducted that compare the effects of different exercise intensities, particularly in water aerobics. In response to this issue, the following two studies were conducted.

The second study showed that 12 weeks of high-intensity water aerobics was more effective than moderate-intensity water aerobics in improving body composition [particularly fat mass (FM) and fat-free mass], lipid profile [including total cholesterol (TC) and triglycerides (TG)], diastolic BP, and physical QoL. It also showed that high and moderate intensity led to improvements in upper and lower muscular endurance and psychological QoL in adults and older adults. When the water aerobics programs that were implemented lasted 24 weeks (Study 3), it was found that high-intensity water aerobics produced better results than moderate-intensity water aerobics. High-intensity exercise resulted in greater improvements in FM, fat-free mass, TC, TG, diastolic BP, and physical QoL. In addition, both intensity levels were found to contribute positively to improvements in muscular endurance. Regardless of program duration, high intensities were highly significant for several variables. This significance may be due to several factors, including: i) an increase in the speed of execution. For example, when speed is doubled, the drag force exerted by the water may be quadrupled, resulting in a corresponding increase in resistance (Poyhonen et al., 2002). By exerting maximum effort during exercise to achieve high or maximal speeds while maintaining full range of motion, the benefits of resistance are increased (Andrade et al., 2020; Moreira et al., 2013), with metabolic cost and neuromuscular activity similar to those experienced on land (Alberton et al., 2011; Becker, 2009; Jones et al., 2011); ii) increased exercise intensity while immersed in water increases energy expenditure and promotes greater adaptations (Costa et al., 2018b; Lambert et al., 2015); iii) the combination of hydrostatic pressure and buoyancy effects may improve outcomes in some parameters. Although it may not always be possible to reach the desired speed during all sessions, these specific characteristics of water can effectively compensate for this, especially for individuals with lower physical conditioning or specific health concerns (Bunæs-Næss et al., 2023).

Despite these findings, the two experimental studies showed no changes in explosive strength, body mass, body mass index (BMI), systolic BP, resting heart rate (HR), general QoL, or the social relationship and environmental domains of QoL, regardless of the intensity and duration of water aerobics performed. To explain this lack of significant results in explosive strength, it has been suggested that the level of muscular stress induced by the exercises was probably lower than what the muscle groups were accustomed to (Colado et al., 2009b). The resistance provided by the water may not have been sufficient to induce significant changes, suggesting the need for exercises with greater impact and higher external resistance (Colado et al., 2009b). With respect to body mass and BMI, the lack of significant changes can be attributed to changes in FM and fat-free mass. For example, in the HIG of both studies, FM decreased at a similar rate to the increase in fat-free mass. As a result, it is normal for body mass and BMI to remain unchanged. In addition, while there were no significant changes in systolic BP, almost all interventions reduced BP by at least 2 mmHg. This magnitude of benefit may be sufficient to reduce mortality from stroke by approximately 10% and from ischemic heart disease by 7% (Prospective Studies Collaboration, 2002). These findings may not be statistically significant, but they are important to exercise and health professionals because they suggest that participation in water aerobics can help maintain or slightly improve cardiovascular health and reduce the risk of some cardiovascular diseases in adults and older adults.

In addition, elevated resting HR increases the potential risk of developing cardiovascular disease and mortality (Fox et al., 2007; Jensen et al., 2012; Sajadieh et al., 2004). Therefore, it was necessary to understand the effects of different water aerobics programs on this particular health measure. In this sense, no changes in resting HR were found and better results should be expected when exercise programs are performed in warmer water (Bergamin et al., 2014; Nuttamonwarakul et al., 2014). It is important to note that, despite the lack of improvement, the resting HR values before and after water aerobics remained consistently below the tachycardia threshold, which is between 90 and 100 beats per minute (Fox et al., 2007). Overall QoL also did not improve with the interventions, likely due to the results in the following areas: social relationship - contrary to the findings of Costa et al. (2018a), the programs in question did not provide sufficient opportunities for social interaction and the development of emotional connections. This may be due to the fact that participants were more focused on performing the exercises; as well as the environmental domain, which includes aspects related to healthcare, recreation, financial resources, and individual safety (Fleck et al., 2000). Thus, this lack of improvement may be attributed to the different environmental conditions in different countries, which may include limited access to healthcare, leisure activities, or financial resources (Haider et al., 2016), rather than solely the specific intervention implemented.

The previous studies did not determine whether the observed effects were solely due to exercise intensity and/or duration or were also influenced by other variables. Therefore, the following two studies were conducted. These studies were designed to analyze the relationship between several variables (such as program intensity and duration, age of participants, and baseline values of certain variables) and the observed changes in muscular strength (Study 4) and cardiovascular health (Study 5) resulting from water aerobics. The following baseline variables were excluded from analysis in both studies: resting HR, body mass, fat-free mass, and the subdomains of QoL. The rationale for their exclusion was based on the presence of collinearity with other variables examined. For example, resting HR showed collinearity with BP. Body mass and fat-free mass were collinear with body mass and BMI, whereas the subdomains of QoL showed collinearity with overall QoL. Moreover, in Study 4, both the lipid profile and BP were excluded before the start of water aerobics because of their lack of relevance in predicting muscle strength after the intervention. Similarly, baseline muscle strength values were not included in the analysis of study 5 because they were not relevant in predicting cardiovascular health after water aerobics programs.

Study 4 showed that the muscular endurance, body composition, and age of the participants significantly influenced the muscular strength gained from water aerobics programs. Specifically, the results showed that the level of muscular endurance before beginning the water aerobics program had a positive relationship with both muscular endurance and explosive strength results after the intervention. Increased strength facilitates the performance of exercises at higher speeds, thereby increasing the resistance encountered in the water (Colado et al., 2009a; Yu et al., 1994). As a result, when the resistance to be overcome is greater, the recruitment of motor units with elevated excitation thresholds is enhanced (Kanitz et al., 2015). This, in turn, increases the potential for gains in various components of muscular strength.

Body composition was also important for the development of explosive strength in adults and older adults. The study suggests that lower FM and BMI prior to water aerobics programs are associated with improved explosive movements after the interventions. This negative relationship is often observed because elevated body fat levels can impair the ability to perform fast movements due to the additional weight that must be mobilized (Ding & Jiang, 2020; Michalakis et al., 2013; Orssatto et al., 2020). However, it is important to maintain a balanced level of FM. Extremely low levels of FM can also lead to increased fragility, decreased muscle strength, increased risk of osteoporosis, and impaired physical function (An & Shi, 2015; Brady et al., 2014; Yuan et al., 2021). As a result, very low and very high fat levels may adversely affect the ability to performed explosive strength (Fosstveit et al., 2023; Rauner et al., 2013). In addition, the age of the participants influenced the results of muscular strength after the interventions. Younger individuals showed greater explosive strength in their lower limbs, while older individuals demonstrated greater muscular endurance in their upper limbs after participating in water aerobics programs. Research consistently shows that muscle strength generally declines with age, which is often associated with sarcopenia and an increase in FM as people age (Cruz-Jentoft & Sayer, 2019; Gallagher et al., 2000; Häkkinen et al., 1998; Ohkawa et al., 2005; Perroni et al., 2015; Rahemi et al., 2015). This age-related decline in strength is particularly significant when comparing explosive strength with muscular endurance. The contrasting results observed in muscular endurance and explosive strength suggest that external factors may also play a role in the strength levels achieved.

Interestingly, the intensity of water aerobics appears to be critical for the development of lower limb muscular endurance in adults and older adults. Intensity was related to lower limb muscular endurance, with high-intensity water aerobics being associated with better results than moderate intensities. The greater involvement of the lower extremities in all exercises may explain these findings. This relationship is significant because increasing lower limb muscular endurance contributes to the improved functional capacity in adults and older adults (Cruz-Montecinos, 2024), thereby facilitating the performance of activities of daily living (Yamada et al., 2012). On the other hand, intensity was not found to be related to upper limb muscular endurance and explosive strength results after the interventions. Perhaps the stimulus was not specific for this type of purpose or not enough for the necessary adaptations. For example, performing each exercise more than 25 times in a row may be challenging for strength gains in the context of aquatic exercise (Moreira et a., 2013). Nevertheless, a recent aquatic high-intensity interval training program (Sette et al., 2024) demonstrated increases in muscular endurance of the lower and upper limbs through specific strength exercises with fewer repetitions per exercise. This highlights the importance of exercise specificity and load (e.g., exercise speed, repetitions, intervals, intensity).

In terms of program duration, no significant relationship was observed with any of the strength variables achieved after water aerobics. In fact, while some 12- and 24-week water aerobics programs have reported improvements in strength (Colado et al., 2009c; Moreira et al., 2017; Tsourlou et al., 2006; Waters & Hale, 2007), other programs of equivalent duration have not yielded similar results. For example, Neiva et al. (2018) observed an increase in the upper explosive strength indices following a 12-week water aerobics program. However, no significant changes were observed in lower limb explosive strength or muscular endurance. In addition, López et al. (2017) and Novais et al. (2014) conducted a water aerobics program for 12 and 24 weeks, respectively. Both found improvements in muscular endurance of the lower limbs, but they did not have the same effect on the upper limbs. These findings, together with the results of the present study, suggest that the duration of water aerobics classes may not be the most important factor to consider when aiming to improve upper limb muscle endurance and lower and upper limb explosive strength in adults and older adults. Instead, and as previously reported, the specific exercises selected, the number of repetitions performed for each exercise, and the prolonged use of aquatic equipment throughout the session may be important in increasing strength adaptations.

The fifth study in this thesis highlighted the importance of the intensity during water aerobics programs on health outcomes. The higher intensity had a positive effect on the lipid profile of adults and older adults after water aerobics. Immersion in an aquatic environment, along with the increased energy expenditure of high intensity classes, resulted in a significant decrease in TC and TG concentrations in both adults and older adults (Costa et al., 2018b; Kasprzak & Pilaczyńska-Szcześniak, 2014; Marrugat et al., 1996; Thompson et al., 1997). Additionally, the longer duration of the program, 24 weeks, was critical for achieving favorable results in diastolic BP. Although Studies 2 and 3 showed a reduction in diastolic BP after 12 or 24 weeks of water aerobics of high intensity, the results of Study 5 indicated that the 24-week duration had a more pronounced effect. Of the studies that specified the intensity used, only those that included 24 weeks of water aerobics reported significant improvements in diastolic BP (Novaes et al., 2014; Sobczak et al., 2023). Shorter durations did not show significant changes (Moura et al., 2020; Neiva et al., 2018), with the exception of Study 2 in this thesis, which found improvements, but only with high-intensity exercise. Therefore, it can be suggested that 12 to 24 weeks of high-intensity water aerobics training is highly beneficial for reducing diastolic BP, with the longer duration maximizing the gains.

This fifth study showed a strong influence of initial TC levels on BP measured after water aerobics programs. Higher initial TC levels were associated with increased BP after these programs. These findings are consistent with the existing literature (Bønaa & Thelle, 1991; Munakata, 2015; Pereira et al., 2006; Laurenzi et al., 1990), which indicates that higher TC levels in the bloodstream are strongly associated with the buildup of plaque in the arterial walls. Over time, this accumulation exacerbates the narrowing and stiffening of the arteries. The progression of this process contributes significantly to the development of atherosclerosis and can raise BP (Chen et al., 2021; Humphrey et al., 2016; Kubozono et al., 2017). High BP further increases the risk of cardiovascular events, making cholesterol management critical for maintaining cardiovascular health and preventing related complications (Mozaffarian et al., 2008). Overall, high-intensity water aerobics appears to reduce the risk of cardiovascular events.

This thesis contributes to the knowledge of the optimal intensity and duration for performing water aerobics in adults and older adults to maximize various health-related variables. Nevertheless, it is important to recognize the limitations that should be addressed: i) the specificity of the sample is limited by the fact that only women participated, which limits the generalizability of the findings and prevents comparisons with men; ii) a larger sample size within each experimental group would have the potential to reduce the possibility of Type II errors occurring, thereby increasing the statistical power and overall robustness of the findings; iii) the inclusion of a control group in experimental studies would facilitate a basis for comparison, allowing a clearer understanding of whether the observed results were solely due to the intervention and the factors described in Studies 4 and 5, or whether they were influenced by additional external factors, such as lifestyle or behavioral changes; iv) the lack of monitoring of participants' dietary habits and medication; v) the inclusion of cardiorespiratory fitness and balance assessments in experimental studies could have provided valuable insights.

Chapter 5. Overall Conclusions

The current thesis provides evidence that high intensities of water aerobics, compared to moderate intensities, produce more beneficial effects on several health-related variables in adults and older adults. Specifically, several key conclusions can be drawn from the findings, including:

i. The literature lacks sufficient studies that evaluate and compare the exercise intensity of water aerobics;

ii. High-intensity water aerobics is more effective than moderate-intensity water aerobics, regardless of program duration, for improving lipid profiles (TC and TG), body composition (FM and fat-free mass), diastolic BP, and physical QoL;

iii. Both durations of high-intensity water aerobics are beneficial for diastolic BP, with the most effective results observed at 24 weeks;

iv. Both water aerobics programs improve muscular endurance at 12 and 24 weeks, with the high-intensity program associated with better lower limb muscular endurance;

v. Performing 12 weeks of water aerobics improves psychological QoL;

vi. Water aerobics at moderate and high intensities for 12 and 24 weeks does not appear to be sufficient to change explosive strength, body mass, BMI, systolic BP, resting HR, or general, social relationships, and environmental QoL;

vii. The muscular endurance of the upper limbs and the explosive strength obtained by water aerobics are related to the initial values of muscular endurance and to the age of the participants. Explosive strength after the interventions is related to body composition;

viii. The lipid profile achieved by water aerobics is primarily due to the intensity of the exercise, while diastolic BP is influenced by the duration of the program, especially if it is 24 weeks. Additionally, initial TC levels are positively associated with BP achieved after the water aerobics program.

Chapter 6. Suggestions for Future Research

The findings presented in this thesis are highly relevant to water aerobics instructors. However, the applicability of this activity to diverse audiences highlights the need to expand the research to different populations and extend the assessments. Therefore, several recommendations for future studies are provided below:

i. Replicate these studies with larger sample sizes while controlling for dietary intake;

ii. Analyze more variations in exercise intensity (e.g., low vs. moderate vs. high intensity) and with longer intervention periods (e.g., ≥ 24 weeks);

iii. Compare the health-related adaptations produced by water aerobics programs of different intensities across different age groups (young adults vs. adults vs. older adults) and gender (female vs. male);

iv. Evaluate differences in adaptations between healthy populations and those with chronic diseases;

v. Assess the effects of water aerobics on additional health and fitness variables, including bone density, balance, cardiorespiratory fitness, and various anthropometric measures (such as skinfolds, waist and hip circumferences, and waist-to-hip ratio);

vi. Investigate how baseline anthropometric parameters and cardiorespiratory fitness influence the benefits of water aerobics.

Chapter 7. References

Chapter 1. General Introduction

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Chapter 3. Study 2

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Chapter 4. General Discussion

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Appendix

Response letter to Aquatic exercise in adults with chronic disease: evidence of benefit for individuals with Hypertension

Dear Editor,

We thank Dr Ciolac (2023) for his interest in our systematic review with meta-analysis about the effects of water-based training on the health status and physical fitness of healthy adults and adults with diseases (Faíl et al., 2022). Overall, we highlighted the effects on balance, cardiorespiratory fitness and strength in healthy adults, whereas balance, quality of life, strength, pain, and gait were improved in individuals with chronic diseases. Furthermore, useful recommendations for health and sports professionals were provided (Faíl et al., 2022). We recognize that some limitations should be addressed and the results should be carefully analyzed, considering the methodological procedures (e.g., inclusion and exclusion criteria). Yet, the limitations should not refrain professionals and researchers from critically interpreting our results and then developing new investigations to fill some gaps in the literature and/or designing water-based training programs for specific populations.

The comments provided by Dr Ciolac (2023) did not compromise our findings and should be seen as a complement to the analysis provided. As in any review paper with large databases, the screening process is not easy and, despite being completed by different researchers, some processual errors can occur. Nevertheless, we confirmed all our search results and reasons can be provided for the non-included studies. For example, the use of specific terms could lead to article exclusion because of their experimental condition (e.g., thermo-mineral spring water; heated water-based) (Arazi et al., 2020; Cruz et al., 2017; Guimarães et al., 2014; Guimarães et al., 2018). Moreover, manuscripts were excluded from meta-analysis if they did not aim to analyze the effect of a water-based training period and/or the non-presentation of full methods that would allow replication and/or the lack of specific data results (Arazi et al., 2020; Arca et al., 2018; Cruz et al., 2017; Guimarães et al., 2014; Guimarães et al., 2018; Ruangthai et al., 2020; Woo-Cheol et al., 2016). In the specific case of individuals with hypertension, with the suggestions provided and considering the existing data, we performed a simple meta-analysis and the estimate of the effect was found to be −1.84 (95% CI: −2.92, −0.76; I^2 of 85%) for diastolic and −2.62 (−4.97, −0.27; I^2 of 96%) for the systolic blood pressure, favoring the intervention (Cruz et al., 2017; Guimarães et al., 2014; Woo-Cheol et al., 2016). Although we have only used the studies that provided full specific data results, this tended to show positive results of water-based training on adults with hypertension, as we tend to suggest in our review.

We believe that our review (Faíl et al., 2022) summarizes the current state of research, highlighting the clearest effects of water-based training in healthy adults and adults with diseases, but at the same time, discussing some limitations of included studies. Besides the main findings and practical suggestions, this review was intended to stimulate discussion and provide future directions for studying the effects of water-based training.

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