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Tese de Doutorado

Treinamento aeróbio no meio aquático: efeitos crônicos na aptidão física e parâmetros de intensidade utilizados na prescrição de adultos e idosos

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bell hooks

Resumo

ANDRADE, Luana Siqueira. **Treinamento aeróbio no meio aquático: efeitos crônicos na aptidão física e parâmetros de intensidade utilizados na prescrição de adultos e idosos.** Orientadora: Cristine Lima Alberton. 2023. 204 f. Tese (Doutorado em Educação Física) - Programa de Pós-Graduação em Educação Física, Escola Superior de Educação Física, Universidade Federal de Pelotas, Pelotas.

A presente tese de doutorado teve como objetivo revisar a literatura disponível sobre 1) os efeitos de programas de treinamento aeróbio no meio aquático sobre os componentes da aptidão física relacionada à saúde (capacidade cardiorrespiratória, força muscular, equilíbrio e flexibilidade) de adultos jovens e idosos, e; 2) comparar os parâmetros de consumo de oxigênio (VO_2), frequência cardíaca (FC) e índice de esforço percebido (IEP) nas intensidades máxima e associada ao limiar anaeróbio entre os ambientes aquático e terrestre em indivíduos saudáveis. Em relação ao primeiro estudo, três bases de dados (PubMed, LILACS e EMBASE) foram pesquisadas em abril de 2022. Os critérios de elegibilidade incluíram ensaios randomizados e não randomizados com programas de treinamento aeróbio realizados por adultos jovens e idosos analisando componentes de aptidão física (capacidade cardiorrespiratória, força muscular, equilíbrio e flexibilidade). Foram realizadas meta-análises de efeitos aleatórios comparando programas de treinamento aeróbio no meio aquático e 1) grupos de controle, 2) programas de treinamento aeróbio no meio terrestre e 3) programas de treinamento combinado no meio aquático. Foram apresentadas a diferença média (DM) e intervalo de confiança (IC) de 95% quando os estudos incluídos relataram as variáveis utilizando a mesma escala de medida ou a diferença média padronizada (DMP) e IC de 95% para variáveis que utilizaram medidas distintas. A qualidade metodológica dos estudos foi medida pela *Tool for the Assessment of Study Quality and Reporting in Exercise* (TESTEX). Vinte e um estudos foram incluídos na revisão e 15 na meta-análise. Todos os estudos incluídos na meta-análise tiveram a amostra composta por idosos. Em comparação com o controle, os resultados mostraram um aumento significativo na capacidade cardiorrespiratória (DM = 3,32 $ml.kg^{-1}.min^{-1}$; IC 95% 2,48 a 4,16) após programas de treinamento de 8 a 24 semanas. Na força muscular máxima foram observados incrementos (DM = 3,03 kg; IC 95% 1,62 a 4,44) após programas de 10 a 12 semanas, enquanto na força muscular medida por testes funcionais foram observadas melhorias (DMP = 1,68; IC 95% 0,80 a 2,56) em programas de até 8 meses. Nenhuma diferença foi observada para agilidade/equilíbrio dinâmico (DMP = 0,34; IC 95% -0,04 a 0,72) e flexibilidade (DM = 3,39 cm; 95% IC -1,22 a 8,00). Além disso, não foram observadas diferenças nos ganhos de capacidade cardiorrespiratória entre os programas de treinamento aeróbio aquático e terrestre (DM = 3,23 $ml.kg^{-1}.min^{-1}$; IC 95% -2,45 a 8,91). Ainda, o treinamento aeróbio foi superior ao treinamento combinado na melhora das respostas cardiorrespiratórias (DMP = 0,58; IC 95% 0,15 a 1,01) com incrementos semelhantes na força muscular (DMP = -0,04; IC 95% -0,38 a 0,30) e agilidade/equilíbrio dinâmico (DMP = 0,17; IC 95% -0,18 a 0,51). Em relação ao segundo estudo, quatro bancos de dados (PubMed, LILACS, EMBASE e SPORTDiscus) foram pesquisados em setembro de 2020. Os critérios de elegibilidade incluíram estudos com design cruzado comparando testes incrementais aquáticos e terrestres realizados por indivíduos saudáveis e parâmetros cardiorrespiratórios analisados no esforço máximo (ou seja, VO_{2max}, FC_{max}, IEP_{max}) ou associado ao limiar anaeróbio (ou seja, VO_{2LAn}, FC_{LAn}, IEP_{LAn}). A meta-análise de efeitos aleatórios incluiu a DM e IC de 95% para o VO_2 e a FC ou DMP para o IEP. A qualidade metodológica dos estudos foi avaliada por meio de uma versão adaptada da *Joanna Briggs Institute (JBI) Critical Appraisal tool for Analytical Cross-Sectional Studies*. Vinte e oito estudos foram elegíveis e incluídos na meta-análise. Os resultados demonstraram que os protocolos aquáticos apresentaram valores inferiores aos terrestres para VO_{2max} (DM = -7,07 $ml.kg^{-1}.min^{-1}$; 95% IC -8,43 a -5,70), VO_{2LAn} (DM = -6,19 $ml.kg^{-1}.min^{-1}$; 95% IC - 7,66 a -4,73), FC_{max} (DM = -11,71 bpm; 95% IC -13,84 a -9,58) e FC_{LAn} (DM = -15,29 bpm; 95% IC -19,05 a -11,53). Os valores de IEP_{max} (DMP = 0,01; 95% IC -0,16 a 0,18) e IEP_{LAn} (DMP = -0,67; 95% IC -1,35 a 0,02) foram semelhantes entre os protocolos aquático e terrestre. Em síntese, os resultados desta tese indicam que, além de melhorias nos parâmetros cardiorrespiratórios, o treinamento exclusivamente aeróbico no meio aquático também pode aumentar a força muscular em idosos. Por sua vez, para que os benefícios dos programas de treinamento aeróbico sejam alcançados de forma eficaz e segura, a prescrição baseada em parâmetros fisiológicos (VO_2 e FC) deve levar em consideração a especificidade do ambiente. Por outro lado, o IEP parece ser uma medida intercambiável da intensidade do exercício entre os ambientes aquático e terrestre.

Palavras-chave: Consumo de oxigênio. Força muscular. Equilíbrio. Flexibilidade. Índice de esforço percebido.

Abstract

ANDRADE, Luana Siqueira. **Aerobic training in the aquatic environment: chronic effects on physical fitness and intensity parameters used in the prescription of young and older adults.** Advisor: Cristine Lima Alberton. 2023. 204 p. Thesis (PhD in Physical Education) - Postgraduate Program of Physical Education, Superior School of Physical Education, Federal University of Pelotas, Pelotas.

This doctoral thesis aimed to review the available literature on 1) the effects of aerobic training programs in the aquatic environment on components of physical fitness related to health (cardiorespiratory capacity, muscle strength, balance, and flexibility) of young and older adults, and; 2) compare the parameters of oxygen consumption (VO_2), heart rate (HR) and rating perceived exertion (RPE) at maximum intensities and the anaerobic threshold between aquatic and land environments by healthy individuals. Regarding the first study, three databases (PubMed, LILACS, and EMBASE) were searched in April 2022. Eligibility criteria included randomized and non-randomized trials with aerobic training programs performed by young and older adults analyzing components of physical fitness (cardiorespiratory capacity, muscle strength, balance, and flexibility). Random effects meta-analyses were performed comparing aquatic aerobic training programs and 1) control groups, 2) land aerobic training programs, and 3) aquatic combined training programs. The mean difference (MD) and 95% confidence interval (CI) were presented when the included studies showed the variables using the same measurement scale or the standardized mean difference (SMD) and 95% CI for variables that used different measures. The methodological quality of the studies was assessed by the Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX). Twenty-one studies were included in the review and 15 in the meta-analysis. All studies included in the meta-analysis had a sample of older adults. Compared with the control, the results showed a significant increase in cardiorespiratory capacity (MD = 3.32 $ml.kg^{-1}.min^{-1}$; 95% CI; 2.48 to 4.16) after training programs of 8 to 24 weeks. In the maximum muscular strength, increments were observed (MD = 3.03 kg; 95% CI 1.62 to 4.44) in programs of 10 to 12 weeks, while in the muscle strength measured by functional tests, improvements were observed (SMD = 1.68; 95% CI 0.80 to 2.56) in programs of up to 8 months. No difference was observed for agility/dynamic balance (SMD = 0.34; CI 95% -0.04 to 0.72) and flexibility (MD = 3.39 cm; 95% CI -1.22 to 8.00). In addition, no differences were observed in gains in cardiorespiratory capacity between aquatic and land aerobic training programs (MD = 3.23 $ml.kg^{-1}.min^{-1}$; 95% CI -2.45 to 8.91). Furthermore, aerobic training was superior to combined training in improving cardiorespiratory responses (SMD = 0.58; 95% CI 0.15 to 1.01) with similar increments in muscle strength (SMD = -0.04; 95% CI -0.38 to 0.30) and agility/dynamic balance (SMD = 0.17; CI 95% -0.18 to 0.51). Regarding the second study, four databases (PubMed, LILACS, EMBASE, and SPORTDiscus) were searched in September 2020. Eligibility criteria included studies with crossover design comparing aquatic and land incremental tests performed by healthy individuals and analyzed cardiorespiratory parameters at maximal effort (i.e., VO_{2max}, HR_{max}, RPE_{max}) or associated at anaerobic threshold (i.e., VO_{2AT}, HR_{AT}, RPE_{AT}). The random-effects meta-analysis included MD and 95% CI for VO_2 and HR or SMD for RPE. The methodological quality of the studies was assessed using an adapted version of the Joanna Briggs Institute (JBI) Critical Appraisal tool for Analytical Cross-Sectional Studies. Twenty-eight studies were eligible and included in the meta-analysis. The results demonstrated that the aquatic protocols presented lower values than land protocols for VO_{2max} (MD = -7.07 $ml.kg^{-1}.min^{-1}$; 95% CI -8.43 to -5.70), VO_{2AT} (MD = -6.19 $ml.kg^{-1}.min^{-1}$; 95% CI -7.66 to -4.73), HR_{max} (MD = -11.71 bpm; 95% CI -13.84 to -9.58) and HR_{AT} (MD = -15.29 bpm; 95% CI -19.05 to -11.53). The RPE_{max} (SMD = 0.01; 95% CI -0.16 to 0.18) and RPE_{AT} (SMD = -0.67; 95% CI -1.35 to 0.02) values were similar between the aquatic and land protocols. In summary, the results of this thesis indicate that, in addition to improvements in cardiorespiratory parameters, exclusively aerobic training in the aquatic environment can also increase muscle strength in older adults. In turn, for the benefits of aerobic training programs to be achieved effectively and safely, the prescription based on physiological parameters (VO_2 and HR) must take into account the specificity of the environment. On the other hand, RPE appears to be an interchangeable measure of exercise intensity between aquatic and land environments.

Keywords: Oxygen uptake. Muscle strength. Balance. Flexibility. Rating of perceived exertion.

Sumário

APRESENTAÇÃO

A presente tese de doutorado, exigência para obtenção do título de Doutora pelo Curso de Doutorado em Educação Física do Programa de Pós-Graduação em Educação Física é composta pelos seguintes itens:

1) Projeto de Pesquisa modificado de acordo com as sugestões da banca avaliadora, Prof. Dra. Ana Carolina Kanitz e Prof. Dr. Rodrigo Sudatti Delevatti, defendido em 28 de março de 2022.

2) Relatório de atividades desenvolvidas durante o curso de Doutorado.

3) Artigo 1 intitulado "*Effects of aquatic aerobic training on physical fitness in young and older adults: a systematic review and meta-analysis*".

4) Artigo 2 intitulado "*Cardiorespiratory parameters comparison between incremental protocols performed in aquatic and land environments by healthy individuals: a systematic review and meta-analysis*".

5) Anexos do trabalho.

PROJETO DE PESQUISA

Resumo

ANDRADE, Luana Siqueira. **Treinamento aeróbio no meio aquático: efeitos crônicos na aptidão física e parâmetros de intensidade utilizados na prescrição de adultos e idosos.** Orientadora: Cristine Lima Alberton. 2022. Projeto de Pesquisa (doutorado) – Programa de Pós-Graduação em Educação Física, Universidade Federal de Pelotas, Pelotas/RS.

O presente trabalho tem como objetivo revisar a literatura disponível sobre efeitos crônicos de programas de treinamento aeróbio no meio aquático na aptidão física de adultos e idosos e sobre parâmetros de prescrição utilizados na prescrição. Serão apresentados dois estudos que pretendem: 1) investigar os efeitos de programas de treinamento aeróbio no meio aquático em componentes da aptidão física relacionados à saúde (capacidade cardiorrespiratória, força muscular, flexibilidade e equilíbrio) de adultos e idosos e; 2) comparar os parâmetros de consumo de oxigênio (VO_2), frequência cardíaca (FC) e índice de esforço percebido (IEP) nas intensidades máxima e no limiar anaeróbio entre os meios aquático e terrestre por indivíduos saudáveis. Ressalta-se que o estudo 1 ainda não foi iniciado e o estudo 2 já está em andamento, em fase de análise dados. Com relação ao primeiro estudo serão pesquisadas as seguintes bases de dados: PubMed, LILACS e EMBASE. Os critérios de elegibilidade incluirão ensaios randomizados e não randomizados que investigaram efeitos de programas de treinamento exclusivamente aeróbios em diferentes modalidades aquáticas realizados na posição vertical sobre variáveis relacionadas à aptidão física de adultos e idosos. A qualidade dos estudos foi avaliada pela *Tool for the assessment of study quality and reporting in exercise* (TESTEX). Com relação ao segundo estudo, quatro bases de dados (PubMed, LILACS, EMBASE e SPORTDiscus) foram pesquisadas. Os critérios de elegibilidade incluíram estudos com desenho cruzado comparando testes incrementais aquáticos e terrestres realizados por indivíduos saudáveis que analisaram parâmetros cardiorrespiratórios no esforço máximo (VO_{2max}, FC_{max}, IEP_{max}) ou no limiar anaeróbio (VO_{2LAn}, FC_{LAn}, IEP_{LAn}). A qualidade metodológica dos estudos foi avaliada por uma versão adaptada da *Joanna Briggs Institute (JBI) Critical Appraisal tool for Analytical Cross-Sectional Studies*. Serão apresentadas a diferença média e intervalo de confiança (IC) de 95% quando os estudos incluídos relatarem os resultados das variáveis utilizando a mesma escala de medida ou a diferença média padronizada e IC de 95% para variáveis que utilizarem medidas distintas. Para ambos os trabalhos, serão realizadas meta-análises de efeitos aleatórios quando dois ou mais estudos relatarem a mesma variável.

Palavras-chave: Consumo de oxigênio. Frequência cardíaca. Índice de esforço percebido. Capacidade cardiorrespiratória. Força muscular. Flexibilidade. Equilíbrio.

1. Introdução

Exercícios realizados no meio aquático na posição vertical têm ganhado popularidade, como alternativa aos exercícios físicos convencionais realizados no meio terrestre (por exemplo, caminhada/corrida, ciclismo ou dança), provavelmente por algumas vantagens proporcionadas pelas propriedades físicas da água. Como consequência da força de empuxo, os exercícios aquáticos são tradicionalmente recomendados por proporcionarem um baixo impacto nas articulações dos membros inferiores de seus praticantes (ALBERTON et al., 2015, 2019a). Nesse sentido, o meio aquático fornece um ambiente com segurança osteoarticular para seus participantes e essa característica favorece a aderência em programas de exercícios aquáticos de indivíduos que apresentam alguma dificuldade para realizar exercícios no meio terrestre.

Com relação aos efeitos crônicos da realização de exercícios no meio aquático, parece que programas de treinamento aeróbio podem apresentar como vantagem adicional características e adaptações de treinamento multicomponente (ou seja, adaptações em três ou mais componentes da aptidão física) (COSTA et al., 2018). Estudos têm demonstrado que o treinamento aeróbio no meio aquático é capaz de gerar, além de melhorias nos parâmetros cardiorrespiratórios, incrementos em outros componentes da aptidão física como na força muscular (ANDRADE et al., 2020a; BOCALINI et al., 2008; COSTA et al., 2018; HÄFELE et al., 2022a, 2022c; KANITZ et al., 2015; RICA et al., 2013; SILVA et al., 2018), na flexibilidade (BOCALINI et al., 2008; REICHERT et al., 2016) e no equilíbrio dinâmico (BOCALINI et al., 2008; REICHERT et al., 2016; SILVA et al., 2018). Tais adaptações adicionais podem ser atribuídas especialmente à sobrecarga imposta pelo próprio meio, devido à força de arrasto gerada pelo movimento na água, e ao empuxo que proporciona instabilidade durante os exercícios (TORRES-RONDA; SCHELLING I DEL ALCÁZAR, 2014). Além disso, é importante mencionar que o treinamento aeróbio parece ser mais eficiente que os programas de treinamento combinado (KANITZ et al., 2015) e de força (COSTA et al., 2018) para melhorar as respostas cardiorrespiratórias, com incrementos semelhantes nas respostas de força muscular.

Nos últimos anos, revisões sistemáticas com meta-análises têm apresentado à comunidade científica evidências mais consistentes sobre os efeitos de programas de treinamento realizados no meio aquático sobre componentes da aptidão física de adultos e idosos (FAÍL et al., 2022; KIM et al., 2020; KWOK et al., 2022; PRADO et al., 2016; REICHERT et al., 2015; WALLER et al., 2016). Reichert et al. (2015) demonstraram que programas de hidroginástica proporcionam incrementos na capacidade funcional de indivíduos idosos. Da mesma forma, Waller et al. (2016) demonstraram que programas de treinamento no meio aquático parecem ser eficazes na melhora de diversas variáveis da aptidão física (força muscular máxima, resistência muscular, agilidade, flexibilidade, habilidade de caminhar e capacidade aeróbia) e no funcionamento físico autorreferido. É importante mencionar que as conclusões desses estudos foram baseadas no agrupamento de diferentes modelos de treinamento (ou seja, aeróbios, de força ou combinados), sem análises de subgrupos por tipo de exercício, logo, informações sobre adaptações específicas de cada modelo não foram apresentadas.

Destaca-se que os exercícios aeróbios são bastante preconizados nas recomendações de exercícios (CHODZKO-ZAJKO et al., 2009; GARBER et al., 2011; PESCATELLO et al., 2004), principalmente pelos benefícios proporcionados na saúde cardiovascular dos praticantes, uma vez que uma baixa aptidão cardiorrespiratória é preditor de mortalidade por todas as causas e eventos cardiovasculares (KODAMA et al., 2009). Sendo assim, as pesquisas sobre as adaptações cardiorrespiratórias e neuromusculares do treinamento aquático exclusivamente aeróbio ganharam destaque principalmente na última década (ANDRADE et al., 2020a, 2020b; COSTA et al., 2018; HÄFELE et al., 2022a, 2022c; KANITZ et al., 2015; PASETTI; GONÇALVES; PADOVANI, 2012; REICHERT et al., 2016; RICA et al., 2013; SILVA et al., 2018) e provavelmente por ser uma temática explorada recentemente, não foi encontrada nenhuma revisão sistemática da literatura atual sobre esse tópico. Sintetizar os resultados de programas de treinamento exclusivamente aeróbios no meio aquático pode fornecer uma melhor resposta acerca da efetividade desse modelo sobre diferentes parâmetros da aptidão física relacionados à saúde de adultos e idosos.

Em adição as vantagens de caráter biomecânico proporcionadas pelo meio aquático (ou seja, empuxo e força de arrasto), diversos parâmetros fisiológicos são alterados em decorrência de algumas características da água, especialmente pela ação da pressão hidrostática e da termocondutividade diferenciada (PENDERGAST; LUNDGREN, 2009; PENDERGAST et al., 2015). Essas alterações têm implicações em parâmetros cardiorrespiratórios, sendo assim a prescrição e o monitoramento da intensidade de exercícios no meio aquático requerem atenção, visto que estão diretamente relacionadas à segurança e efetividade de programas de treinamento. O consumo de oxigênio (VO_2) e a frequência cardíaca (FC) são indicadores de intensidade amplamente utilizados no meio aquático (HÄFELE et al., 2022a, 2022b, 2022c; JONES; MEREDITH-JONES; LEGGE, 2009; KANITZ et al., 2015; PINTO et al., 2015b; SILVA et al., 2018; TSOURLOU et al., 2006) e afetados pela imersão. Portanto, a prescrição por esses parâmetros não pode levar em consideração apenas o comportamento fisiológico do corpo humano em meio terrestre. Além disso, o índice de esforço percebido (IEP) também é amplamente utilizado no controle da intensidade em programas de exercícios no meio aquático (ANDRADE et al., 2020a; REICHERT et al., 2016), mas possíveis diferenças com o meio terrestre ainda precisam ser elucidadas.

Embora estudos comparando o comportamento de parâmetros cardiorrespiratórios (VO_2, FC e IEP) durante testes incrementais entre os meios aquático e terrestre sejam desenvolvidos desde a década de 1990 (ALBERTON et al., 2013a, 2014; BROWN et al., 1996a; BUTTS; TUCKER; GREENING, 1991; FRANGOLIAS; RHODES, 1995; KANITZ et al., 2014; KRUEL et al., 2013; MERCER; JENSEN, 1998; TIGGEMANN et al., 2007; YAZIGI et al., 2013), não foi encontrada nenhuma revisão sistemática e síntese da literatura sobre esse tema. Resumir essas diferenças pode fornecer uma melhor orientação sobre as respostas em cada ambiente. Assim, esses achados ajudarão a entender a necessidade de testes incrementais específicos no meio aquático, a fim de auxiliar na prescrição e monitoramento da intensidade adequada durante a prática de exercício nesse meio.

Portanto, o presente trabalho abordará parâmetros de intensidade e efeitos crônicos da realização de exercícios aeróbios no meio aquático. Serão apresentados dois estudos que buscam sumarizar (1) os efeitos crônicos de programas de treinamento aeróbio no meio aquático em componentes da aptidão física relacionados a saúde de adultos e idosos, assim como (2) os achados sobre parâmetros cardiorrespiratórios empregados na prescrição da intensidade de programas de treinamento aeróbio comparando as respostas máximas e associadas ao limiar anaeróbio entre os meios aquático e terrestre.

1.1 Objetivo Geral

Revisar a literatura disponível sobre os efeitos crônicos de programas de treinamento aeróbio no meio aquático na aptidão física, assim como os parâmetros de intensidade utilizados na prescrição dos programas de treinamento de adultos e idosos.

1.2 Objetivos Específicos

Artigo 1: Investigar os efeitos de programas de treinamento aeróbio no meio aquático em componentes da aptidão física relacionados à saúde (capacidade cardiorrespiratória, força muscular, flexibilidade e equilíbrio) de adultos e idosos, revisando ensaios randomizados e não randomizados.

Artigo 2: Comparar os parâmetros de VO_2, FC e IEP nas intensidades máxima e no limiar anaeróbio entre os meios aquático e terrestre, revisando estudos transversais cruzados que compararam protocolos de testes máximos nessas duas condições realizadas por indivíduos saudáveis.

2. Revisão de Literatura

2.1 Propriedades físicas da água e seus efeitos no corpo imerso

A imersão no meio aquático oferece condições distintas comparadas ao meio terrestre. Sendo assim, os benefícios e vantagens proporcionados pela realização de exercícios no meio aquático estão relacionados às propriedades físicas da água. Coletivamente, as características da água provocam efeitos biológicos únicos que podem favorecer algumas adaptações fisiológicas ao exercício. Assim, compreender essas características é fundamental para uma prescrição de exercícios segura e eficaz nesse meio.

Inicialmente é importante considerar que a densidade é a relação entre a massa e o volume de uma substância. No caso de um fluido, quanto maior sua densidade maior a força que ele exerce sobre os objetos que flutuam ou estão imersos nele. Destaca-se que a densidade da água doce à 4°C é 1,0 g/cm^3, enquanto a densidade do ar é 0,001 g/cm^3. A partir da densidade específica poderemos saber se algum corpo flutuará ou afundará quando imerso em água (ou seja, densidade específica = densidade da substância/densidade da água), sendo assim, corpos com densidades inferiores a da água flutuarão e corpos com densidades superiores a da água afundarão. É importante notar que a densidade do corpo humano é ligeiramente menor que a da água, apresentando uma densidade média de 0,97 g/cm^3, embora esse valor varie de acordo com o sexo, o somatótipo e a idade (BECKER, 2009). Nesse sentido, a massa magra, que inclui ossos, músculos, tecido conjuntivo e órgãos, tem uma densidade próxima de 1,1 g/cm^3, enquanto a massa gorda tem uma densidade próxima de 0,9 g/cm^3 (BLOOMFIELD; FRICKER; FITCH, 1992).

Com relação ao empuxo, deve-se considerar que ele é uma força, unidirecional de baixo para cima, que um fluído exerce sobre um corpo submerso. Quando se trata da força de empuxo é imprescindível falar do Princípio de Arquimedes, que afirma que "Todo corpo, parcial ou totalmente, imerso em um fluído sofre uma força igual ao peso do volume de líquido deslocado por esse fluído, com sentido contrário à força gravitacional da terra". Sendo assim, um corpo imerso está submetido a duas forças em oposição, a força da gravidade e a força de empuxo, fazendo com que os corpos imersos apresentem um peso hidrostático, ou peso aparente, inferior ao apresentado em terra. Nesse contexto, é importante considerar que a profundidade de imersão exerce influência na redução do peso hidrostático, sendo que quanto maior a profundidade de imersão, maior a redução do peso hidrostático (FINKELSTEIN et al., 2004; HARRISON; HILLMAN; BULSTRODE, 1992; KRUEL, 1994).

Com relação a redução do peso hidrostático na profundidade do processo xifoide, estudos demonstraram reduções de aproximadamente 70% em adultos jovens eutróficos (ALBERTON et al., 2013b, 2015; HARRISON; HILLMAN; BULSTRODE, 1992). Além disso, foram observadas reduções de 68% em pacientes com diabetes tipo 2 (DELEVATTI et al., 2015), 72% em crianças com obesidade (GOMES et al., 2021), 75% em mulheres pós-menopáusicas (ALBERTON et al., 2021a), 79,5% em idosas (ALBERTON et al., 2019a), 81% em mulheres com obesidade (ALBERTON et al., 2021b) e 83% na 32ª semana gestacional (ALBERTON et al., 2019b). Tais diferenças na magnitude da redução do peso hidrostático entre os estudos citados podem ser explicadas pelas diferenças na composição corporal (massa muscular, massa gorda e densidade óssea) dos participantes (TORRES-RONDA; SCHELLING I DEL ALCÁZAR, 2014).

Consequentemente, a redução do peso hidrostático resulta em uma menor força de reação vertical do solo (Fz) conforme evidenciado durante diferentes formas de exercício no meio aquático, como caminhada aquática (BARELA; DUARTE, 2008; BARELA; STOLF; DUARTE, 2006; MIYOSHI et al., 2004; NAKAZAWA; YANO; MIYASHITA, 1994; NUNES et al., 2020), saltos (COLADO et al., 2010; TRIPLETT et al., 2009) e exercícios de hidroginástica (ALBERTON et al., 2013b, 2015; DE BRITO FONTANA et al., 2015, 2012; DELEVATTI et al., 2015; HAUPENTHAL et al., 2010), em comparação com os mesmos exercícios realizados no meio terrestre. Em virtude dessa menor sobrecarga mecânica nas articulações dos membros inferiores, o meio aquático apresenta como vantagem uma maior segurança osteoarticular, na qual favorece a aderência de indivíduos que apresentam alguma dificuldade para realizar exercícios no meio terrestre em programas de exercícios aquáticos.

Outra vantagem para as atividades aquáticas de caráter biomecânico fornecida pelo ambiente aquático está relacionada á resistência imposta pela água em todos os sentidos de movimento. Conforme observamos anteriormente, a densidade da água é muito maior que do ar fazendo com que a resistência imposta pela água durante a realização de exercícios no meio aquático seja maior (DI PRAMPERO, 1986; DOWZER; REILLY; CABLE, 1998). Além da densidade (ρ) outros fatores também influenciam na força de arrasto, sendo eles o coeficiente de arrasto (Cd), a área projetada (A) e a velocidade (V), conforme pode ser observado pela equação geral dos fluidos $Fd = 0,5 \cdot Cd \cdot \rho \cdot A \cdot V^2$ (ALEXANDER, 1977).

O coeficiente de arrasto é relacionado ao formato do objeto que é deslocado, por exemplo o coeficiente de arrasto de um de um cubo é maior que o de uma esfera, sendo que quanto menor o coeficiente, melhor a "hidrodinâmica", ou seja, menor será a resistência ao movimento. Com relação a área projetada, podemos observar que quanto maior a área de superfície projetada maior é a resistência imposta pela água e, portanto, a força necessária para mover o item através da água. Essa variável pode ser manipulada utilizando diferentes exercícios, com maiores ou menores áreas projetadas ou com a utilização de equipamentos aquáticos. Nesse sentido, estudos observaram maiores respostas cardiorrespiratórias durante a execução de exercícios de hidroginástica com a utilização de equipamentos resistidos em comparação com a execução sem equipamento (PINTO et al., 2006, 2008, 2011).

Com base na equação, é importante observar que a força de arrasto fornecida pela água é fortemente influenciada pela velocidade do movimento, uma vez que é elevada ao quadrado e diretamente proporcional a ela. Como reflexo disso, alguns estudos têm sugerido que as associações entre o aumento da intensidade e parâmetros cardiorrespiratórios durante testes incrementais nem sempre são lineares e podem apresentar relações polinomiais (ANDRADE et al., 2020c; BRESSEL et al., 2012; DAVID et al., 2017). Especificamente, relações polinomiais foram observadas entre VO_2 e carga da esteira aquática (BRESSEL et al., 2012), assim como entre $\%VO_{2pico}$, $\%FC_{max}$ e IEP com o aumento da cadência (ANDRADE et al., 2020c; DAVID et al., 2017) em diferentes protocolos aquáticos incrementais até a exaustão. Portanto, isso deve ser levado em consideração para a prescrição da intensidade do exercício no meio aquático e também para determinar a progressão da carga de treinamento, principalmente em intensidades elevadas. Além disso, é importante notar que a velocidade de execução tem grandes implicações em programas de treinamento de força, na qual se propõe a utilização da velocidade máxima para a execução dos movimentos e o controle do tempo de execução da série para enfatizar as vias metabólicas desejadas como uma forma de controlar a intensidade dos exercícios (SOUZA et al., 2010).

Além disso, a força de arrasto apresenta consequências no tipo de contração muscular no ambiente aquático. Durante repetições múltiplas de flexão e extensão de joelho no meio aquático, Pöyhönen et al. (2001) observaram uma diminuição precoce da atividade concêntrica dos músculos agonistas com ativação concomitante dos músculos antagonistas. Por outro lado, durante a realização do exercício com repetições simples (apenas em um sentido do movimento), a atividade neuromuscular antagonista foi baixa com atividade prolongada dos músculos agonistas durante toda a amplitude de movimento. As velocidades angulares mostraram valores semelhantes entre os exercícios simples e de múltiplas repetições demonstrando que a alteração no padrão de atividade neuromuscular é decorrente da continuidade das repetições e não de possíveis alterações na velocidade de execução.

Adicionalmente, algumas propriedades físicas da água apresentam implicações de caráter fisiológico. Quando imerso, um corpo sofre a ação da pressão hidrostática em toda a superfície corporal que está imersa e consequentemente os efeitos fisiológicos começam imediatamente após a imersão. A Lei de Pascal indica que a pressão do líquido é exercida igualmente sobre todas as áreas da superfície de um corpo imerso e em repouso a uma determinada profundidade e essa pressão aumenta proporcionalmente à profundidade e à densidade desse líquido (SKINNER; THOMSON, 1985). Assim, a pressão hidrostática facilita o retorno venoso, fazendo com que um grande volume de sangue seja deslocado das regiões periféricas para as centrais do corpo, aumentando o volume sanguíneo intratorácico (ARBORELIUS et al., 1972).

Além disso, a maior termocondutividade da água também contribui para o aumento do volume sanguíneo central (PENDERGAST; LUNDGREN, 2009; PENDERGAST et al., 2015). Os mecanismos de transferência de calor na água e da terra são distintos, visto que no meio terrestre a transferência de calor ocorre por meio da evaporação, enquanto em situação de imersão a transferência de calor acontece por condução e convecção, fazendo com que a água seja considerada um condutor mais eficiente de calor, transferindo calor 25 vezes mais rápido que o ar. Assim, a necessidade de distribuir sangue da região central (tórax e abdômen) para a periferia é diminuída. Além disso, em contraste com o que ocorre em exercício no meio terrestre, cuja a evaporação e consequente perda hídrica pode levar a uma redução do volume sanguíneo, a transferência de calor por meio da condução e convecção faz com que ocorra uma eficiente troca de calor com o meio externo com mínima perda hídrica, levando a um aumento no volume plasmático, que conjuntamente com a ação da pressão hidrostática acaba repercutindo em um aumento de volume sanguíneo central (JOHANSEN et al., 1998).

Assim, a associação desses dois mecanismos (isto é, pressão hidrostática e termocondutividade) é responsável pela hipervolemia central, tornando necessários ajustes fisiológicos em decorrência dessa hemodinâmica diferenciada. Com o aumento do volume plasmático na região central, o coração e os vasos da circulação central são distendidos, gerando estimulação nos receptores de volume e pressão desses tecidos. Isso conduz à uma readaptação no sistema cardiovascular, aumentando a pressão venosa central, volume sistólico e o débito cardíaco, levando a uma diminuição da FC que pode ser entendida como compensatória (ARBORELIUS et al., 1972). Com relação a magnitude da redução da FC em imersão cabe destacar que ela é influenciada por alguns fatores, como a temperatura da água (CRAIG; DVORAK, 1966; GRAEF et al., 2005; ŠRÁMEK et al., 2000), a profundidade de imersão (FINKELSTEIN et al., 2004 KRUEL, 1994; KRUEL et al., 2014) e a FC inicial (KRUEL, 1994; KRUEL et al., 2014) de cada indivíduo.

Consequentemente, o VO_2, que é o produto do débito cardíaco e da diferença arteriovenosa, também sofre os efeitos da imersão. Em repouso, como consequência do aumento do débito cardíaco em imersão, alguns estudos observaram valores semelhantes de VO_2 entre ambientes aquáticos e terrestres (CHRISTIE et al., 1990; PARK et al., 1999; SCHMID et al., 2007), enquanto outros encontraram um leve aumento (ALBERTON et al., 2013c; KRUEL et al., 2006; MEKJAVIC; BLIGH, 1989). A redistribuição sanguínea com aumento da concentração do volume sanguíneo na região central repercute em um aumento da passagem de sangue pelo coração e pulmões levando a uma maior captação de oxigênio pelo sangue, proporcionando aumento do VO_2 (MEKJAVIC; BLIGH, 1989).

Com relação a realização de exercícios, no meio terrestre o débito cardíaco aumenta devido à maior demanda metabólica. No entanto, os exercícios realizados em meio aquático revelam um débito cardíaco maior do que em terra, para uma carga de trabalho equivalente (PARK et al., 1999; PENDERGAST; LUNDGREN, 2009). Tal aumento do débito cardíaco não implica em VO_2 proporcional como em terra, pois a diferença arteriovenosa é menor na água. Portanto, independentemente da ocorrência de redistribuição sanguínea para os músculos ativos, esse aumento do débito cardíaco não seria direcionado de forma expressiva para esses grupos musculares. Nesse sentido, alguns estudos têm demonstrado que o VO_2 máximo e submáximo (ou seja, na intensidade associada ao LAn) é significativamente menor no ambiente aquático em relação ao terrestre (ALBERTON et al., 2013a, 2014; BROWN et al., 1996a; BUTTS; TUCKER; GREENING, 1991; FRANGOLIAS; RHODES, 1995; KANITZ et al., 2014; KRUEL et al., 2013; MERCER; JENSEN, 1998; TIGGEMANN et al., 2007).

Tendo em vista as alterações proporcionadas pelas propriedades físicas da água, observa-se que a prescrição de exercícios no meio aquático não deve levar em consideração apenas o comportamento do organismo no meio terrestre. No próximo tópico serão apresentados parâmetros utilizados para a prescrição de exercícios aquáticos considerando as características do meio.

2.2 Prescrição de exercícios aeróbios no meio aquático

A estruturação de um programa de exercícios aeróbios envolve a manipulação de diversas variáveis; uma delas é a intensidade, que merece uma consideração fundamental na hora de adequar a prescrição de exercícios aeróbios, visto que o controle está diretamente relacionado à eficácia do programa de exercícios (GARBER et al., 2011). Os exercícios aeróbios são prescritos de acordo com a intensidade relativa, projetados para produzir cargas de estresse equivalentes em indivíduos com diferentes capacidades físicas absolutas e permitir respostas adaptativas mais previsíveis (MANN; LAMBERTS; LAMBERT, 2013).

Dentre vários parâmetros para monitorar a intensidade, as abordagens tradicionais têm sido prescrever a intensidade do exercício como percentual do VO_{2max} ou da FC_{max} (MANN; LAMBERTS; LAMBERT, 2013), devido à sua relação linear com a intensidade durante testes incrementais (FRANKLIN; HODGSON; BUSKIRK, 1980; KATCH et al., 1978; SWAIN et al., 1994). Além disso, os parâmetros cardiorrespiratórios associados ao limiar anaeróbio (LAn) podem ser utilizados como uma forma mais precisa e individualizada de prescrever a intensidade dos exercícios aeróbios, uma vez que o LAn é o ponto de transição entre a predominância do sistema aeróbio para o anaeróbio (MANN; LAMBERTS; LAMBERT, 2013; WASSERMAN et al., 1973). Além disso, o IEP é uma possibilidade prática para o controle da intensidade, que está diretamente relacionada ao $\%VO_{2max}$ e $\%FC_{max}$ (ANDRADE et al., 2020c; CHEN; FAN; MOE, 2002; DUNBAR et al., 1992; ROBERTSON et al., 2000) e ao LAn em diversas modalidades exercício (ALBERTON et al., 2016; HETZLER et al., 1991; SCHERR et al., 2013). No entanto, para esses parâmetros mencionados, os valores de referência podem ser influenciados por diversos fatores, como o ambiente e os equipamentos utilizados. Assim, para evitar valores percentuais subestimados ou superestimados, a referência deve ser alcançada em um protocolo de teste máximo que considere a especificidade do exercício na prática real.

O ambiente aquático oferece uma possibilidade alternativa para o treinamento físico. Dentre as modalidades de exercício aquático, podem ser destacadas aquelas realizadas em piscina rasa ou funda (por exemplo, exercícios de hidroginástica, caminhada/corrida em piscina rasa, corrida em piscina funda) ou em ergômetros aquáticos (por exemplo, esteiras ou cicloergômetros), ambos em posição vertical. No entanto, como visto anteriormente, a imersão na água expõe o corpo humano a condições distintas comparadas ao meio terrestre, causando alterações fisiológicas devido à ação de propriedades físicas específicas da água (PENDERGAST; LUNDGREN, 2009; PENDERGAST et al., 2015).

Nesse sentido, diferentes parâmetros podem ser utilizados para a prescrição de exercícios aeróbios no meio aquático, todavia, torna-se indispensável considerar as características do ambiente para que a escolha seja adequada. Por exemplo, embora o VO_2 seja considerado o parâmetro padrão-ouro para a prescrição de exercícios aeróbios, sua aplicação é restrita à pesquisa, visto que a utilização desse parâmetro é inviável na prática de clubes e academias. Assim, outros parâmetros podem ser utilizados durante a prescrição e controle da intensidade de exercícios aeróbios, como a FC, o IEP ou a cadência de execução. Neste tópico serão apresentadas as características, assim como as vantagens e desvantagens dos diferentes parâmetros que podem ser utilizados durante a prescrição de exercícios no meio aquático.

Consumo de oxigênio e frequência cardíaca

O VO_2 e a FC no esforço máximo e na intensidade associada ao LAn são indicadores de intensidade amplamente utilizados no meio aquático (KANITZ et al., 2015; MEREDITH-JONES; LEGGE; JONES, 2009; PINTO et al., 2015b; SILVA et al., 2018; TSOURLOU et al., 2006). Todavia, a imersão no meio aquático influência as respostas cardiorrespiratórias durante o exercício. Para demonstrar as diferenças entre terra e água, desde a década de 1990, estudos com corrida em piscina funda compararam o comportamento de parâmetros cardiorrespiratórios no esforço máximo e no LAn entre os dois ambientes (BUTTS; TUCKER; GREENING, 1991; FRANGOLIAS; RHODES, 1995). Mais recentemente, esses parâmetros também foram investigados em ergômetros aquáticos (SCHAAL; COLLINS; ASHLEY, 2012; YAZIGI et al., 2013) e em exercícios em piscina rasa (ALBERTON et al., 2013a, 2014; NAGLE et al., 2017) para entender os efeitos da imersão durante testes incrementais em diferentes modalidades de exercício.

Assim, a literatura relacionada às diferenças entre os meios indica que as respostas cardiorrespiratórias durante o exercício, seja em intensidade de esforço máximo ou submáximo, são significativamente menores no meio aquático comparado ao terrestre (ALBERTON et al., 2013a, 2014; BROWN et al., 1996a; BUTTS; TUCKER; GREENING, 1991; FRANGOLIAS; RHODES, 1995; KANITZ et al., 2014; KRUEL et al., 2013; MERCER; JENSEN, 1998; TIGGEMANN et al., 2007). É importante notar que a utilização dos valores de VO_2 e FC medidos no meio terrestre na prescrição de exercícios aquáticos pode colocar os praticantes em maior risco cardiovascular, uma vez que superestima a intensidade do treinamento. Assim, é indicado que os valores de referência para a adaptação de uma zona alvo de treinamento devem ser alcançados em um protocolo de teste máximo que considere a especificidade do exercício na prática real para evitar valores percentuais subestimados ou superestimados.

Em uma revisão sistemática, Ogonowska-Slodownik et al. (2020) descreveram propriedades específicas de protocolos de testes cardiorrespiratórios empregados no ambiente aquático. Os autores observaram que os protocolos revisados foram altamente diversificados e não existe um protocolo aquático amplamente aceito para avaliar a aptidão cardiorrespiratória. Além disso, com base nos protocolos analisados, sugeriram três propriedades-chave de testes para uso clínico: (1) temperatura da água de 28 a 30ºC com diferença máxima de 1ºC entre os participantes e/ou sessões de teste, (2) profundidade da água adaptada para experiências e habilidades aquáticas dos participantes e (3) incrementos na intensidade de 10 a 15 batidas por minuto. No entanto, esse estudo não buscou comparar as respostas cardiorrespiratórias máximas e submáximas entre os protocolos de testes máximos aquáticos e protocolos padrão em meio terrestre. Dessa forma, reside a lacuna na literatura quanto a magnitude da diferença das respostas cardiorrespiratórias entre meios aquático e terrestre.

Ponto de deflexão da frequência cardíaca

Considerando a relevância do LAn na prescrição de exercícios aeróbios como uma alternativa mais precisa e individualizada, é importante notar que as formas padrão-ouro de determinação do LAn utilizam os métodos ventilatórios (LV) ou de lactato (LL). Esses métodos são considerados métodos inviáveis na prática de clubes e academias, pois necessitam de equipamentos sofisticados, além da determinação do lactato ser um procedimento invasivo. Como forma alternativa, o ponto de deflexão da FC (PDFC) pode ser considerado como um método de determinação de LAn mais prático, menos custoso e não invasivo, visto que se baseia na relação curvilínea entre FC e intensidade de esforço (CONCONI et al., 1982).

O PDFC foi validado utilizando a modalidade de corrida no meio terrestre (CONCONI et al., 1982) e nos últimos anos a aplicação desse método para a determinação do LAn tem sido investigada em exercícios no meio aquático (ALBERTON et al., 2013d, 2021c; ANDRADE et al., 2020d; KANITZ et al., 2014; KRUEL et al., 2013; PINTO et al., 2016). Baseado nesses estudos, a FC correspondente ao PDFC têm mostrado ser semelhante àquela determinada pelo segundo limiar ventilatório em exercícios de hidroginástica (ALBERTON et al., 2013d; KRUEL et al., 2013) e na modalidade de corrida em piscina funda (KANITZ et al., 2014) em protocolos realizados por mulheres jovens.

De maneira consecutiva, os estudos mais recentes (ALBERTON et al., 2021c; ANDRADE et al., 2020d; PINTO et al., 2016) têm investigado a concordância entre os métodos utilizando a análise de Bland-Altman, que é o método indicado para determinar se as duas medidas são equivalentes e se uma pode substituir a outra (MARTIN BLAND; ALTMAN, 1986). Sendo assim, foram observados valores semelhantes e concordância dos valores de FC correspondentes ao LAn entre os métodos LV e PDFC durante testes incrementais máximos em cicloergômetro aquático realizado por homens jovens (PINTO et al., 2016) e com exercício de corrida estacionária realizado por mulheres idosas (ANDRADE et al., 2020d). Adicionalmente, também foram observados valores semelhantes e concordância no valor de FC correspondente ao LAn entre os métodos LL e PDFC em testes com o exercício de corrida estacionária realizado por homens jovens (ALBERTON et al., 2021c).

O uso da FC associada ao LAn determinada pelo PDFC como parâmetro de prescrição da intensidade de exercícios no meio aquático é uma estratégia eficaz para atender o princípio da individualidade biológica, visto que com base no PDFC é possível calcular porcentagens abaixo ou acima do LAn para prescrever a intensidade da zona de treinamento desejada. Além disso, destaca-se que estudos já verificaram benefícios do treinamento aeróbio no meio aquático prescrito pelo PDFC em parâmetros de saúde em idosos e indivíduos diabéticos (COSTA et al., 2018; DELEVATTI et al., 2016, 2018; HÄFELE et al., 2022a, 2022b, 2022c; KANITZ et al., 2015; SILVA et al., 2018). É importante destacar que o PDFC pode ser determinado a partir de um teste simples, barato e não invasivo, utilizando apenas um monitor de FC e um metrônomo ao longo de um teste incremental máximo estruturado para o meio aquático.

Índice de esforço percebido

O IEP é definido como a intensidade subjetiva de esforço, tensão, desconforto e/ou fadiga sentido ou experimentado durante exercícios aeróbicos e resistidos (ROBERTSON; NOBLE, 1997), e, é uma possibilidade prática para o controle da intensidade que está diretamente relacionada à parâmetros fisiológicos (VO_2 e FC) conforme demonstrado em diferentes modalidades e exercícios aquáticos (ALBERTON et al., 2016; ANDRADE et al., 2020c; BROWN et al., 1996b; DAVID et al., 2017; SHONO et al., 2000). Adicionalmente, considerando a relevância dos limiares na prescrição de exercícios, a literatura tem demonstrado valores próximos a 16 como correspondentes a intensidade associada ao LAn em exercícios de hidroginástica para mulheres jovens e idosas (ALBERTON et al., 2013a, 2016; ANDRADE et al., 2020d).

Com relação a comparação entre os meios, os estudos não apresentam diferença nos valores de IEP entre os meios aquático e terrestre (ALBERTON et al., 2013a; BROWN et al., 1996a; FRANGOLIAS; RHODES, 1995; GREENE et al., 2011; MASUMOTO et al., 2018), assim o IEP pode ser considerado um parâmetro de prescrição intercambiável entre os meios. Tal característica pode ser considerada uma vantagem do uso do IEP para prescrever intensidade no meio aquático, justamente porque com essa ferramenta parece ser possível evitar a influência direta dos efeitos fisiológicos da imersão e garantir uma prescrição de intensidade adequada, sem a necessidade de testes específicos.

A utilização do IEP como parâmetro de prescrição em programas de exercício aquático apresenta como vantagem a maior validade externa, uma vez que é uma alternativa para a prescrição da intensidade de sessões de treinamento realizadas por populações especiais como idosos, que frequentemente fazem uso de medicamentos (por exemplo, betabloqueadores) que influenciam nas respostas cardiovasculares (ESTON; CONNOLLY, 1996). Além disso, sua aplicação pode ser facilmente implementada para prescrição de exercícios no meio aquático, por ser uma ferramenta de baixo custo, simples e de fácil aplicabilidade para aulas em grupo.

É importante destacar que estudos comprovam a efetividade da prescrição de exercícios pelo IEP, demonstrando incrementos após programas de exercícios de 12-28 semanas em parâmetros cardiorrespiratórios, neuromusculares, funcionais, de qualidade de vida e pressão arterial (ANDRADE et al., 2020a, 2020b; REICHERT et al., 2016). Por outro lado, para que o método seja válido e adequado para atingir a intensidade desejada e garantir os benefícios potencias de programas de exercício no meio aquático dois pontos devem ser observados: 1) a escala deve ser posicionada de maneira visível para todos os alunos durante todas as aulas; 2) é indispensável despender tempo nas primeiras sessões do programa de treinamento para que sejam fornecidas informações suficientes sobre a aplicação desse método, ou seja, os indivíduos devem ser familiarizados e para isso devem experimentar todas as âncoras numéricas da escala.

Cadência musical

A cadência musical é uma das ferramentas empregadas no controle da intensidade durante sessões de exercícios aquáticos por alguns treinadores. Essa forma de prescrição é geralmente escolhida com o objetivo de: 1) motivar os praticantes durante a sessão; 2) manter a sincronização dos praticantes durante as sessões e; (3)

atingir uma determinada intensidade de esforço (BARBOSA et al., 2009). Seguindo essa forma de prescrição, músicas que possuem as cadências pretendidas são escolhidas, a fim de atingir uma intensidade de esforço pré-determinada, e o tempo da batida musical é sincronizado com a execução da ação segmentar do exercício aquático (BARBOSA et al., 2009).

Incrementos na cadência da música provocam aumentos nas respostas cardiorrespiratórias (ALBERTON et al., 2021a; RAFFAELLI et al., 2010). No entanto, embora seja possível modular a carga de exercício a partir do uso da cadência, seu uso não leva em consideração as diferenças interindividuais nas respostas fisiológicas ao exercício, uma vez que determinada cadência musical pode representar diferentes percentuais de esforço máximo para diferentes indivíduos (ALBERTON et al., 2016). Observando os valores encontrados por Alberton et al. (2013b) de média e desvio padrão da corrida estacionária no segundo limiar ventilatório (134,4 ± 13,1 bpm), pode-se observar que algumas participantes da amostra atingiram o segundo limiar em aproximadamente 121 bpm, enquanto outras em 147 bpm. Assim, ao prescrevermos um exercício em uma cadência de 130 bpm, provavelmente aquelas que atingiram o limiar na cadência de 121 estão em uma zona de treinamento anaeróbia, enquanto aquelas que atingiram o segundo limiar em 147 bpm estarão em uma zona predominantemente aeróbia.

Outra limitação desse método para controlar a intensidade do exercício é que ele não leva em consideração as diferenças entre exercícios. Alguns estudos demonstraram que diferentes exercícios em diferentes cadências pré-estabelecidas, apresentam valores distintos em variáveis cardiorrespiratórias (VO_2, FC e IEP) em mulheres jovens (RAFFAELLI et al., 2010), pós-menopáusicas (ALBERTON et al., 2007) e idosas (NEVES; HÄFELE; ALBERTON, 2021). Os resultados desses estudos indicam que exercícios com maiores áreas projetadas, tanto de membros inferiores quanto de membros superiores, levam a maiores respostas cardiorrespiratórias agudas, em comparação aos exercícios com menores áreas projetadas quando realizados em diferentes cadências fixas (60 - 140 $b.min^{-1}$) (ALBERTON et al., 2007; NEVES; HÄFELE; ALBERTON, 2021; RAFFAELLI et al., 2010). Assim, observa-se que uma cadência musical específica pode corresponder a diferentes intensidades quando diferentes exercícios envolvendo diferentes amplitudes de movimento e grupos musculares são usados ao longo da sessão.

É importante mencionar que dentre os parâmetros abordados para a prescrição de exercícios aeróbios, a cadência é o parâmetro com menor evidências científicas sobre o seu uso. As evidências encontradas foram principalmente associando a cadência a outros parâmetros de controle da intensidade de exercícios aeróbios (ou seja, VO_2, FC e IEP) (ANDRADE et al., 2020c; DAVID et al., 2017; BARBOSA et al., 2010). Com relação aos efeitos de programas de treinamento aeróbio no meio aquático prescritos por cadência, Raffaelli et al. (2016) observaram melhoras significativas na aptidão cardiorrespiratória, força muscular, bem como no equilíbrio e em alguns aspectos da composição corporal de mulheres jovens. Todavia, destaca-se que o estudo de Raffaelli et al. (2016) apresenta como limitação ter um delineamento pré-experimental de grupo único sem grupo controle e por isso é necessário ter cautela na interpretação e generalização dos resultados, uma vez que trabalhos pré-experimentais podem ter sua validade interna questionada. Além disso, a cadência é um marcador de carga externa, fazendo com que a escolha por esse parâmetro suceda em um “chute” na intensidade, assim, além desse marcador não ter precisão para gerar efeito, assume-se uma falta de segurança na prescrição.

A partir do exposto, podemos perceber que a cadência é o parâmetro menos recomendado quando o objetivo é condicionamento cardiorrespiratório, principalmente em turmas heterogêneas, por não levar em consideração o princípio da individualidade biológica. Por outro lado, a utilização de músicas durante as sessões de exercício no meio aquático pode ser pertinente com o objetivo de coordenação ou cognição em aulas coreografadas ou de motivação durante as sessões.

Considerações finais sobre os parâmetros de prescrição de exercícios aeróbios

Diferentes parâmetros podem ser utilizados para a prescrição de exercícios aeróbios no meio aquático, sejam fisiológicos (VO_2 e FC), subjetivos (IEP) ou mecânicos (cadência). Por sua vez, cada método apresenta suas vantagens e desvantagens, sendo que a escolha deve considerar a população envolvida, assim como a preferência e disponibilidade de recursos. Além disso, a cadência parece não ser recomendável com objetivo de condicionamento cardiorrespiratório pela falta de individualização de carga.

Observa-se que embora os estudos comparando as respostas de VO_2, FC e IEP durante testes incrementais entre os meios aquático e terrestre sejam desenvolvidos desde a década de 1990, não foi encontrada nenhuma revisão sistemática e síntese da literatura sobre esse tema. Além disso, destaca-se que o objetivo de uma meta-análise é compilar os resultados de vários estudos para aumentar o tamanho da amostra e fortalecer as evidências sobre determinado tema. Assim, resumir os resultados da comparação de parâmetros cardiorrespiratórios entre os meios pode fornecer uma melhor orientação sobre as respostas em cada ambiente. A comunidade científica que trabalha com exercícios aquáticos necessita de evidências mais consistentes e essa comparação em uma revisão sistemática com meta-análise pode ajudar muitos profissionais a prescreverem programas de exercícios aquáticos de forma mais adequada.

2.3 Efeitos de programas de exercício aeróbio realizados no meio aquático em componentes da aptidão física de adultos e idosos

Os efeitos de programas de treinamento no meio aquático são investigados desde a década de 90, tendo sido encontrado na literatura como precursor o estudo de Taunton et al. (1996). Desde então a literatura relacionada aos efeitos de programas de treinamento no meio aquático vêm sendo expandida. No entanto, a maioria dos estudos que investigaram os efeitos da realização de exercícios no meio aquático foram realizados utilizando programas de treinamento combinado ou multicomponente (ALVES et al., 2004; BRAVO et al., 1997; BENTO et al., 2012; GRAEF et al., 2010; KANITZ et al., 2015; KATSURA et al., 2010; MEREDITH-JONES; LEGGE; JONES, 2009; MOREIRA et al., 2013; PINTO et al., 2013, 2015a, 2015b; SANDERS et al., 2013; TAKESHIMA et al., 2002; TAUNTON et al., 1996; TSOURLOU et al., 2006). Assim, as adaptações proporcionadas por esses modelos de treinamento são derivadas não apenas dos exercícios aeróbios, como também de outros exercícios aplicados (por exemplo, exercícios de força, equilíbrio e flexibilidade).

As pesquisas sobre as adaptações cardiorrespiratórias e neuromusculares do treinamento aquático exclusivamente aeróbio ganharam destaque principalmente na última década (ANDRADE et al., 2020a, 2020b; COSTA et al., 2018; HÄFELE et al., 2022a, 2022c; KANITZ et al., 2015; PASETTI; GONÇALVES; PADOVANI, 2012; REICHERT et al., 2016; RICA et al., 2013; SILVA et al., 2018). O estudo de Rica et al. (2013) verificou os efeitos de um programa de treinamento aeróbio de 12 semanas realizado por mulheres idosas obesas, comparado a um grupo controle. O treinamento era realizado três vezes na semana com sessões de 60 min e a parte principal da aula realizada em uma intensidade correspondente a 70% da FC máxima predita pela idade. Os resultados demonstraram que apenas o grupo experimental apresentou incrementos no desempenho de testes funcionais (tempo para caminhar 800 m, *arm curl* e 30-s *chair stand*). Em um estudo anterior, Bocalini et al. (2008) já haviam verificado os efeitos do mesmo programa de treinamento apresentado por Rica et al. (2013) comparado a um programa de caminhada no meio terrestre e a um grupo controle. Após 12 semanas, ambos os grupos de treinamento foram capazes de aumentar o VO_{2max} das participantes, no entanto, o aumento do grupo que realizou exercícios no meio aquático foi maior comparado ao grupo que realizou caminhada no meio terrestre, e apenas no grupo que realizou os exercícios no meio aquático reduziu os valores de FC de repouso. Além disso, após o treinamento no meio aquático foi observada melhora no desempenho de todos os testes funcionais avaliados (isto é, *arm curl, 30-s chair stand, 8-foot up and go, sit and reach, back scratch*), enquanto o treinamento no meio terrestre apresentou incremento nos testes *30-s chair stand, 8-foot up and go e sit and reach*. Cabe destacar os valores pós-treinamento do grupo de treinamento no meio aquático foram maiores que do grupo de treinamento no meio terrestre em todos os testes, com exceção do teste de levantar ir e voltar que ambos os meios apresentaram valores semelhantes.

Se tratando de exercícios em alta intensidade, Broman et al. (2006) investigaram os efeitos de um programa de oito semanas, com duas sessões semanas de aproximadamente 45 min, de treinamento em piscina funda de alta intensidade em idosos. A FC alvo foi de 75-85% da FC máxima (atingida durante um teste máximo em cicloergômetro no meio terrestre) e o treinamento consistiu em vários períodos curtos de trabalho e intervalos de descanso. Os resultados demonstraram redução nos valores FC de repouso e aumento nos valores de VO_{2max} e de ventilação do grupo experimental, sem alterações nas variáveis analisadas no grupo controle.

Martínez et al. (2015) tiveram como objetivo verificar os efeitos do treinamento aeróbio no meio aquático sobre a autonomia funcional de mulheres idosas comparado a um grupo controle. O treinamento teve duração de 12 semanas com cinco sessões semanais de 30 minutos. A intensidade dos exercícios foi prescrita por percentuais da FC de reserva, com incremento de 40-50% da FC de reserva nas primeiras seis semanas para 50-60% da FC de reserva nas últimas seis semanas. A FC de reserva foi estimada com a equação FC máxima = 208 - 0,7 x idade. A autonomia funcional foi determinada pelo protocolo do Grupo de Desenvolvimento Latino-Americano para a Maturidade que consiste em teste de caminhada de 10 m, levantar-se de uma posição sentada, levantar-se da posição deitada, levantar-se de uma cadeira e movimentar-se pela casa e vestir e tirar uma camisa. Os resultados demonstraram incrementos no teste de caminhada de 10 m e no índice geral da bateria de teste após a intervenção apenas para o grupo de exercício.

Programas de treinamento aeróbio *versus* outros modelos de treinamento

Alguns estudos compararam os efeitos de programas de treinamento aeróbio com outros métodos de treinamento, como programas de treinamento de força (COSTA et al., 2018) ou combinado (HÄFELE et al., 2022a, 2022c; KANITZ et al., 2015; SILVA et al., 2018) sobre parâmetros cardiorrespiratórios e neuromusculares de idosos. Os achados de Kanitz et al. (2015) demonstraram que 12 semanas, com três sessões semanais, na modalidade de corrida em piscina funda promoveram adaptações positivas em parâmetros cardiorrespiratórios (isto é, FC de repouso, VO_{2pico}, VO_{2LV2}) e de força muscular (isto é, 1RM de extensores de joelho e resistência muscular localizada de flexores e extensores de joelho) de idosos como resposta aos programas aeróbio e combinado. É importante mencionar que o treinamento aeróbio apresentou incrementos superiores nas respostas cardiorrespiratórias, com similares respostas de força, comparado ao treinamento combinado.

Por outro lado, estudos realizados com exercícios em piscina rasa, demonstraram que 12 semanas de treinamento aeróbio e combinado realizados duas vezes na semana foram igualmente eficazes na melhora da aptidão cardiorrespiratória (isto é, VO_{2pico}, VO_{2LV1} e VO_{2LV2}) e da força de membros inferiores (isto é, 1 RM de extensores de joelho) (HÄFELE et al., 2022a), assim como na melhora da capacidade funcional (isto é, no desempenho dos testes *30-s chair stand*, *6-min walk* e *8-foot up and go*) (SILVA et al., 2018). Em um estudo subsequente, Hafële et al. (2022c) buscaram verificar os efeitos de 16 semanas de treinamento aeróbio comparado a 8 semanas de treino aeróbio seguido de 8 semanas de treinamento combinado, assim como de um grupo controle de exercícios terapêuticos. Os resultados demonstraram que os três grupos melhoraram de forma semelhante o desempenho nos testes funcionais *6-min walk*, *30-s chair stand* e *8-foot up and go* com dupla tarefa, sem alterações no desempenho do teste *chair sit-and-reach*.

Comparando as adaptações proporcionadas por programas de força e aeróbio, Costa et al. (2018) observaram que o treinamento aeróbio parece ser mais eficiente em comparação ao treinamento de força para melhora das respostas cardiorrespiratórias (isto é, VO_{2pico}, VO_{2LV2} e tempo de exaustão), enquanto ambos os modelos de treinamento apresentaram incrementos semelhantes na força muscular (isto é, 1 RM de extensão e flexão de joelhos). Destaca-se que o componente aeróbio dos programas de treinamento nos estudos citados acima (COSTA et al., 2018; HÄFELE et al., 2022a, 2022c; KANITZ et al., 2015; SILVA et al., 2018) foram todos prescritos por percentuais da FC associada ao LAn.

Contínuo *versus* Intervalado

Com relação a diferentes modelos de treino aeróbio, alguns estudos compararam programas de treinamento contínuo e intervalado na modalidade de corrida em piscina funda (PASETTI; GONÇALVES; PADOVANI, 2012; REICHERT et al., 2016) e na hidroginástica (ANDRADE et al., 2020a, 2020b). Os achados de Pasetti et al. (2012) demonstraram que 12 semanas de ambos os programas de treinamento aeróbio, prescritos por percentuais da FC de reserva, apresentaram melhora na aptidão cardiorrespiratória de mulheres obesas, a partir do aumento na duração e no ritmo (número de elevações da perna direita/min) de um teste específico de corrida em piscina, todavia, apenas o treinamento intervalado apresentou redução nos valores de FC de repouso. Reichert et al. (2016) demonstraram que 28 semanas de corrida em piscina funda realizada de forma contínua e intervalada e prescrita por IEP promoveram melhorias em diversos parâmetros da aptidão física medidos por testes funcionais (agilidade e equilíbrio dinâmico, flexibilidade de membros inferiores, força de membros superiores e inferiores e capacidade cardiorrespiratória) de idosos. Além disso, ambos os modelos de treinamento (contínuo e intervalado) também promoveram redução nos valores de PAS e PAD, sem diferença entre os grupos.

Na modalidade de hidroginástica, Andrade et al. (2020a) observaram que os programas de treinamento contínuo e intervalado, também prescritos por IEP, promoveram ganhos similares após 12 semanas em parâmetros cardiorrespiratórios (isto é, FC de repouso, VO_{2pico} e tempo de exaustão em teste progressivo em esteira) e neuromusculares (isto é, 1RM e resistência muscular localizada de extensores de joelho, atividade neuromuscular máxima do vasto lateral, espessura e qualidade muscular do quadríceps femoral) de idosas. Os desfechos secundários desse estudo foram publicados em um segundo artigo (ANDRADE et al., 2020b) e demonstraram que ambos os grupos de treinamento (contínuo e intervalado) apresentaram melhora no desempenho nos testes *30-s chair stand* e *6-min walk,* assim como na velocidade habitual da marcha, sem diferença entre os grupos.

Em suma, a literatura têm demonstrado que o treinamento aeróbio no meio aquático é capaz de gerar, além melhorias nos parâmetros cardiorrespiratórios, incrementos em outros parâmetros da aptidão física como na força muscular (ANDRADE et al., 2020a; BOCALINI et al., 2008; COSTA et al., 2018; HÄFELE et al., 2022a, 2022c; KANITZ et al., 2015; RICA et al., 2013; SILVA et al., 2018), na flexibilidade (BOCALINI et al., 2008; REICHERT et al., 2016) e no equilíbrio dinâmico (BOCALINI et al., 2008; REICHERT et al., 2016; SILVA et al., 2018). Todavia, não foi encontrado na literatura nenhum estudo que sintetize os achados sobre os efeitos do treinamento exclusivamente aeróbio no meio aquático.

Revisões sistemáticas com meta-análises

Nos últimos anos, revisões sistemáticas com meta-análises têm apresentado à comunidade científica evidências mais consistentes sobre os efeitos de programas de treinamento realizados no meio aquático sobre componentes da aptidão física de adultos e idosos (FAÍL et al., 2022; IGARASHI; NOGAMI, 2018; KIM et al., 2020; KWOK et al., 2022; PRADO et al., 2022; REICHERT et al., 2015, 2018; SIMAS et al., 2017; WALLER et al., 2016).

Nesse sentido, Reichert et al. (2015) demonstraram que programas de hidroginástica podem ser indicados como uma forma de melhorar a capacidade funcional de idosos. Especificamente, os resultados das meta-análises demonstraram que a prática de hidroginástica promove incrementos na força muscular resistente e na flexibilidade de membros superiores e inferiores, assim como no equilíbrio dinâmico, a partir do desempenho de testes funcionais. Por outro lado, os resultados não foram capazes de demonstrar efeito significativo do desfecho de capacidade cardiorrespiratória, medido pelo teste de caminhada de seis minutos.

Por sua vez, Waller et al. (2016) objetivaram investigar os efeitos do exercício aquático em parâmetros da aptidão física de idosos saudáveis em comparação a grupos controle e a programas de exercício no meio terrestre. Os resultados demonstraram que os programas de treinamento no meio aquático comparado ao controle apresentaram efeito significativo na melhora da força muscular máxima, resistência muscular, agilidade, flexibilidade, habilidade de caminhar, capacidade aeróbia, assim como do funcionamento físico autorreferido, sem diferença para as variáveis de potência muscular e estabilidade postural. Na comparação entre programas aquáticos e terrestres, os resultados demonstraram que os exercícios aquáticos parecem ser tão eficazes quanto programas de treinamento no meio terrestre na força muscular máxima, resistência muscular, agilidade, flexibilidade, habilidade de caminhar e capacidade aeróbia. Adicionalmente, foi observado efeito a favor dos exercícios aquáticos para o funcionamento físico autorreferido.

Alguns estudos se concentraram em adaptações de componentes específicos da aptidão física. Em variáveis de força muscular, Prado et al. (2022) verificaram os efeitos de programas de treinamento no meio aquático realizados por adultos e idosos. Os resultados mostraram melhora significativa na força de preensão manual, no pico de torque isométrico da flexão e extensão unilateral do joelho e nos valores de 1 RM de flexão de cotovelo após a realização de exercícios aquáticos quando comparado aos grupos controles. Para o pico de torque isocinético ($60º.s^{-1}$) da extensão unilateral do joelho, os resultados não mostraram efeito positivo significativo do treinamento aquático em comparação ao grupo controle. Além disso, as meta-análises comparando exercícios terrestres e aquáticos demonstraram que programas de treinamento no meio aquático parecem levar a ganhos de força muscular semelhantes que programas no meio terrestre na força de preensão manual e número máximo de apoios sobre o solo com o joelhos no chão. Em relação a variáveis de equilíbrio, Kim et al. (2020) demonstraram melhorias comparáveis no equilíbrio dinâmico (por exemplo, teste de caminhada de 5 m, teste de caminhada de 10 m, caminhada em tandem para trás), equilíbrio proativo (por exemplo, *Functional Reach Test, Timed Up and Go Test, 8-Foot Up and Go Test*) e baterias de teste de equilíbrio (por exemplo, *Balance Berg Scale* e *Balance Outcome Measure for Elder Rehabilitation*) após programas de exercícios aquáticos em comparação a programas de exercícios realizados no meio terrestre em idosos com 65 anos ou mais.

Faíl et al. (2022) tiveram como objetivo analisar os resultados da pesquisa sobre os efeitos do treinamento aquático no estado de saúde e aptidão física em adultos com e sem doença crônica. No grupo saudável, foram observados efeitos positivos a favor do treinamento aquático no equilíbrio, na capacidade cardiorrespiratória, flexibilidade, qualidade de vida e na força muscular. Por outro lado, as variáveis antropométricas e de pressão arterial não apresentaram efeitos positivos significativos a favor do treinamento aquático. Entre os adultos com doenças, foram observadas melhoras em pacientes com fibromialgia (no equilíbrio e aptidão cardiorrespiratória), doenças ósseas (dor, equilíbrio, flexibilidade e força), doença arterial coronariana (força e antropometria), hipertensão (qualidade de vida), acidente vascular cerebral (qualidade de vida), diabetes (equilíbrio e qualidade de vida), esclerose múltipla (qualidade de vida e equilíbrio) e doença de Parkinson (dor, marcha, aptidão cardiorrespiratória e qualidade de vida). Destaca-se que inúmeras revisões têm sido desenvolvidas verificando os efeitos dos exercícios aquáticos aplicados a populações especiais. Nesses estudos, o enfoque da população e os desfechos clínicos vão além do escopo da presente pesquisa que se remete exclusivamente a indivíduos saudáveis e componentes da aptidão física.

Recentemente, Kwok et al. (2022) realizaram meta-análises de ensaios clínicos randomizados avaliando o efeito do treinamento aquático intervalado de alta intensidade em marcadores de saúde cardiometabólica e física de mulheres. Os resultados revelaram efeito significativo para um tamanho do efeito moderado a favor do treinamento aquático intervalado de alta intensidade em comparação com o controle no aumento do VO_{2pico}, na redução da FC de repouso, e na melhora de força de membros inferiores, a partir do desempenho no teste *chair to stand*. As demais variáveis investigadas (isto é, pressão artéria sistólica e diastólica, percentual de gordura corporal, lipoproteínas de baixa e alta densidade, densidade mineral óssea total e do fêmur, força de extensão e flexão de joelho) não apresentaram efeito significante.

É importante mencionar que as conclusões destes estudos foram baseadas no agrupamento de diferentes modelos de treinamento (ou seja, aeróbios, de força, combinados ou multicomponentes), sem análises de subgrupos por tipo de exercício, logo, informações sobre adaptações específicas de cada modelo não foram apresentadas. Assim, não foi encontrada nenhuma revisão sistemática da literatura atual sobre as adaptações cardiorrespiratórias e neuromusculares de programas de treinamento exclusivamente aeróbio no meio aquático. Sintetizar os resultados sobre essa temática pode fornecer uma melhor resposta acerca da efetividade desse modelo sobre diferentes componentes da aptidão física relacionados à saúde de adultos e idosos, a fim de confirmar se programas aquáticos tem características e adaptações de treinamento multicomponente.

3. Metodologia

Os métodos de cada estudo serão apresentados de maneira separada. Ressalta-se que no momento da qualificação do projeto, o estudo 1 ainda não havia iniciado, enquanto o estudo 2 já estava em fase de análise dos dados.

3.1 Estudo 1: Efeitos do treinamento aeróbio aquático na aptidão física de adultos jovens e idosos: uma revisão sistemática e meta-análise

A revisão sistemática com meta-análise será conduzida e relatada de acordo com as diretrizes do *Cochrane Handbook for Systematic Reviews of Interventions* (HIGGINS et al., 2022) e do PRISMA (MOHER et al., 2009; PAGE et al., 2021). O protocolo da revisão será registrado no PROSPERO após a qualificação do presente projeto.

3.1.1 Critérios de Elegibilidade

Os critérios de elegibilidade foram definidos adotando a estratégia PICOS (isto é, *participants*, *intervention*, *comparator*, *outcome* e *study design*). Além disso, os estudos serão limitados aos idiomas português, inglês e espanhol e aos publicados em periódicos revisados por pares.

<u>Participantes</u>: Serão incluídos estudos com homens e mulheres com mais de 18 anos de idade, sem restrição quanto ao limite superior de idade ou nível de aptidão física. Não serão incluídos estudos que assumissem como critérios de inclusão doenças cardiovasculares, osteoarticulares, neuromusculares, cânceres, deficiências e/ou recuperação pós-cirúrgica.

<u>Intervenções</u>: Serão incluídos estudos que investigaram efeitos de programas de treinamento exclusivamente aeróbios em diferentes modalidades aquáticas (ex.: exercícios estacionários na água, corrida/caminhada em piscina rasa, corrida em piscina funda, esteira aquática ou cicloergômetro aquático) realizados na posição

vertical, com duração mínima de oito semanas, sem restrição ao tempo máximo de duração, assim como, quanto à intensidade, duração da sessão, frequência ou volume.

Comparador: Serão incluídos estudos em que os resultados de programas de treinamento aeróbio no meio aquático foram comparados com grupos de sujeitos que: 1) não realizaram nenhum programa de treinamento (grupos controle) ou; 2) realizaram outra intervenção aeróbia fora do meio aquático ou; 3) realizaram qualquer outra intervenção no meio aquático. Além disso, estudos sem qualquer um dos grupos comparadores mencionados anteriormente também serão incluídos e apresentados apenas na síntese qualitativa.

Desfechos: Serão incluídos estudos que tenham avaliado desfechos de capacidade cardiorrespiratória, força muscular, flexibilidade e equilíbrio. Como exemplo, as seguintes variáveis, com suas respectivas unidades de medida, poderão ser consideradas: a) consumo máximo de oxigênio (VO_{2max}; $ml.kg^{-1}.min^{-1}$); b) tempo de exaustão em testes incrementais (min); c) distância percorrida em testes de caminhada de 6 min (m); d) força dinâmica máxima em testes de repetições máximas (kg); e) resistência muscular localizada (repetições); f) desempenho nos testes *30-s chair stand* (repetições) e g) *arm curl* (repetições); h) desempenho nos testes *chair sit-and-reach* (cm) e i) *back scratch* (cm); j) desempenho nos testes *timed up and go* (s) e k) *8-foot up and go* (s).

Desenho do estudo: Serão incluídos estudos com delineamento de ensaio randomizado e não randomizado. Estudos de revisão, estudos de caso e estudos com delineamento transversal, serão excluídos.

3.1.2 Fontes de informação

O período de buscas está previsto para ocorrer em Abril de 2022. As buscas serão realizadas em três bases de dados eletrônicas para publicações indexadas de texto completo (ou seja, PubMed, LILACS e EMBASE), desde o início da base de dados (data mais antiga) até Abril de 2022. Além disso, as listas de referência dos artigos encontrados serão verificadas manualmente. As estratégias de busca serão estruturadas utilizando descritores palavras-chave. Uma estratégia de busca preliminar por base de dados está apresentada na Tabela 1.

Tabela 1 – Estratégia de busca completa por banco de dados.

Base de dados	**Estratégia de busca**
PubMed	#1 “water-based exercis*”[tiab] OR “aquatic exercis*”[tiab] OR “head-out water-based”[tiab] OR "water running"[tiab] OR “water walking”[tiab] OR “water cycling”[tiab] OR “aquatic cycling”[tiab] OR “deep-water running”[tiab] OR “water-based aerobic exercise”[tiab] OR “water aerobic exercis*”[tiab] OR “underwater walking”[tiab] OR “underwater gait”[tiab] OR “aquajogging”[tiab] OR “hydrogymnastic*”[tiab] OR “water exercise”[tiab] #2 Review[ti] OR Cohort[ti] OR Cross-sectional[ti] OR Observational[ti] OR Case-control[ti] OR "Case report"[ti] OR Meta-analysis[ti] OR Synthesis[ti] OR Consensus[ti] #1 NOT #2
Lilacs	“water-based exercise” OR “water exercise” OR "water running" OR “water walking” OR “water cycling” OR “deep-water running” OR “deep water OR “water-based aerobic exercise” OR “water aerobic exercise” OR “aquatic exercise” OR “aquatic cycling” OR “underwater walking” OR “underwater gait” OR (water AND exercise)
Embase	#1 'water based exercise'/exp OR 'deep water running'/exp OR 'aquatic exercise'/exp OR 'aquatic exercise' OR 'exercise, aquatic' OR 'underwater exercise'/exp OR 'water-based exercis*':ti,ab OR 'aquatic exercis*':ti,ab OR 'head-out water-based':ti,ab OR 'water running':ti,ab OR 'water walking':ti,ab OR 'water cycling':ti,ab OR 'aquatic cycling':ti,ab OR 'water-based aerobic exercise':ti,ab OR 'water aerobic exercis*':ti,ab OR 'underwater walking':ti,ab OR 'underwater gait':ti,ab OR aquajogging:ti,ab OR hydrogymnastic*:ti,ab OR 'water exercise':ti,ab #2 'review':ti OR 'cohort':ti OR 'cross-sectional':ti OR 'observational':ti OR 'case-control':ti OR 'case report':ti OR 'meta analysis':ti OR 'synthesis':ti OR 'consensus':ti #1 NOT #2

3.1.3 Processo de seleção

Todos os artigos encontrados serão importados para o software de gerenciamento de referência *Mendeley Desktop* (versão 1.19.8, Londres, Reino Unido). Inicialmente, as duplicatas serão removidas. Após, os títulos e resumos dos potenciais estudos serão avaliados independentemente por dois revisores, de acordo com os critérios de elegibilidade citados anteriormente. Será realizada uma triagem piloto de 100 artigos para padronização do processo de elegibilidade. As divergências entre o par serão resolvidas por discussão e em caso de dúvidas a opinião de um terceiro avaliador será solicitada. Os resumos que não fornecerem informações suficientes sobre os critérios de inclusão e exclusão serão avaliados no texto completo.

3.1.4 Processo de coleta dos dados

Todos os artigos incluídos após o processo de seleção pelo texto completo passarão para o processo de extração dos dados. Será utilizada uma planilha de dados codificada para extrair os dados de interesse do estudo. Serão coletados os resultados de variáveis relacionadas a capacidade cardiorrespiratória, força muscular, flexibilidade e equilíbrio, medidos antes e após intervenções com programas de treinamento aeróbio no meio aquático e de seus respectivos grupos comparadores. Além disso, as seguintes informações serão coletadas: informações da publicação (ou seja, autores, ano de publicação, periódico, país), características dos participantes (ou seja, tamanho da amostra, idade, sexo, características antropométricas e nível de treinamento), características dos programas de treinamento (ou seja, modalidade/exercícios, duração do programa, frequência, parâmetro de prescrição da intensidade, intensidade, duração da sessão). Os dados serão extraídos por duplicata e as discordâncias sobre a extração dos dados serão discutidas em conjunto, e em caso de dúvidas ou divergências um terceiro avaliador será consultado. Caso algum dado relevante não seja encontrado no texto completo, os autores dos estudos serão contatados.

3.1.5 Avaliação da qualidade dos estudos

A qualidade metodológica dos estudos será avaliada pela Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX) (SMART et al., 2015), especificamente projetada para uso em estudos de treinamento físico. A TESTEX é uma escala de 15 pontos (5 pontos para a qualidade do estudo e 10 pontos para o relatório), sendo que cada quesito recebe '1' ou '0' pelos avaliadores. A escala usa 12 critérios, com alguns critérios marcando mais de um ponto possível para uma pontuação máxima de 15 pontos. Os critérios de qualidade do estudo são: 1) critérios de elegibilidade especificados; 2) randomização especificada; 3) ocultação de alocação; 4) grupos semelhantes na linha de base; 5) cegamento do avaliador (para pelo menos um resultado-chave); enquanto os critérios para o relato do estudo são: 6) medidas de desfecho avaliadas em 85% dos pacientes; 7) análise de intenção de tratar; 8) comparações estatísticas entre grupos relatadas; 9) medidas pontuais e medidas de variabilidade para todas as medidas de resultado relatadas; 10) monitoramento de atividades em grupos controle; 11) a intensidade relativa do exercício permaneceu constante; 12) volume de exercício e gasto energético.

A avaliação será feita em duplicata de forma independente. Um teste piloto será realizado antes do início do processo de avaliação para consolidar e esclarecer os critérios de classificação das ferramentas entre a dupla de revisores. As discordâncias serão resolvidas por discussão entre a dupla ou por consulta com um terceiro avaliador.

3.1.6 Métodos de síntese

Para os desfechos que for possível, as análises serão realizadas utilizando o *software Review Manager* (versão 5.4). As meta-análises serão realizadas por meio do modelo de efeitos aleatórios, e as medidas de efeito serão obtidas pela média, desvio padrão e tamanho da amostra. Serão realizadas meta-análises para cada variável da revisão quando dois ou mais estudos relatarem a mesma variável. As meta-análises serão realizadas comparando programas de treinamento aeróbio no meio aquático com grupos controle e programas de treinamento aeróbio no meio aquático com programas de treinamento no meio terrestre. Os estudos serão ponderados individualmente usando o método da variância inversa. A diferença média com intervalos de confiança (IC) de 95% serão utilizadas para as meta-análises quando os estudos incluídos relatarem os resultados das variáveis utilizando a mesma escala de medida, enquanto que a diferença padronizada com IC de 95% será calculada para variáveis que utilizarem medidas distintas. A heterogeneidade estatística será medida pelo teste qui-quadrado e pelo teste de inconsistência (I^2). A heterogeneidade será considerada significativa com base no valor $p < 0,10$ ou o valor $I^2 > 40\%$. Para variáveis com alta heterogeneidade, poderão ser realizadas análises de sensibilidade de acordo com modalidades, características da intervenção ou da amostra.

3.1 Estudo 2: Comparação de parâmetros cardiorrespiratórios entre protocolos incrementais realizados nos meios aquático e terrestre por indivíduos saudáveis: uma revisão sistemática e meta-análise

A revisão sistemática com meta-análise foi conduzida e relatada de acordo com as diretrizes do *Cochrane Handbook for Systematic Reviews of Interventions* e do *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) (HIGGINS et al., 2022; MOHER et al., 2009; PAGE et al., 2021). O presente estudo foi registrado no *International Prospective Register of Systematic Reviews* (PROSPERO; CRD42020212508).

3.2.1 Critérios de Elegibilidade

Os critérios de elegibilidade são mostrados na Tabela 2. A revisão incluiu estudos transversais cruzados que investigaram as respostas cardiorrespiratórias durante protocolos de testes incrementais até o esforço máximo em diferentes modalidades de exercício aquático realizado na posição vertical (ou seja, exercícios estacionários na água, corrida/caminhada em piscina rasa, corrida em piscina funda, esteira aquática ou cicloergômetro aquático) em comparação com a condição de teste incremental no meio terrestre. Foram incluídos estudos com homens e mulheres saudáveis com mais de 18 anos. Não houve restrição quanto ao limite superior de idade ou ao nível de aptidão física. Os critérios de exclusão incluíram estudos com participantes afetados por doenças cardiovasculares ou metabólicas (por exemplo, diabetes, doença coronariana, dislipidemia), fator de risco de hipertensão ou distúrbios osteoarticulares. Os estudos foram limitados aos idiomas português, inglês e espanhol, publicados em periódicos revisados por pares.

Tabela 2 – Critérios de elegibilidade.

Critérios	**Descrição**
Idioma de publicação	Inglês, português e espanhol
Desenho do estudo	Transversal Cruzado
Participantes	Homens e mulheres saudáveis (≥ 18 anos)
Exposição	Teste incremental até o esforço máximo em qualquer modalidade de exercício aquático realizado na posição vertical (ou seja, exercícios estacionários na água, corrida/caminhada em piscina rasa, corrida em piscina funda, esteira aquática ou cicloergômetro aquático)
Comparador	Teste incremental até o esforço máximo no meio terrestre
Parâmetros	Consumo de oxigênio (VO_{2max} e VO_{2LA}), frequência cardíaca (FC_{max} e FC_{LA}) e índice de esforço percebido (IEP_{max} e IEP_{LA})

3.2.2 Fontes de informação

As buscas foram realizadas em quatro bases de dados eletrônicas (ou seja, PubMed, LILACS, EMBASE e SPORTDiscus) entre 7 e 8 de setembro de 2020. A busca incluiu estudos que vão desde 1946 (início do banco de dados) até setembro de 2020. Além disso, as listas de referências dos artigos recuperados foram verificadas manualmente. As estratégias de busca de literatura foram desenvolvidas usando *Medical Subject Headings* (MeSH) e palavras-chave. As estratégias de busca completa por banco de dados são apresentadas na Tabela 3.

Tabela 3 - Estratégia completa de busca por base de dados.

Base de dados	**Estratégia de busca**
PubMed	#1 “water-based exercis*”[tiab] OR “water-based”[tiab] OR “aquatic exercis*”[tiab] OR aquatic OR “head-out water-based”[tiab] OR "water running"[tiab] OR “water walking”[tiab] OR “water cycling”[tiab] OR “aquatic cycling”[tiab] OR “deep water” OR “deep-water running”[tiab] OR “water-based aerobic exercise”[tiab] OR “water aerobic exercis*”[tiab] OR “underwater walking”[tiab] OR “underwater gait”[tiab] OR “aquajogging”[tiab] OR “hydrogymnastic*”[tiab] OR “water exercise” OR “water environment” OR “aquatic environment” #2 “Physical Exertion”[Mesh] OR “Exercise test”[Mesh] OR “Exercise testing” OR “Cardiopulmonary exercise test”[tiab] OR

	Cardiorespiratory[tiab] OR “Cardiorespiratory respons*”[tiab] OR “Exercise tolerance”[Mesh] OR “Exercise capacity”[tiab] OR “Maximal incremental test”[tiab] OR “Oxygen Consumption”[Mesh] OR “Oxygen uptake”[tiab] OR “Peak oxygen uptake”[tiab] OR “Maximal oxygen consumption”[tiab] OR “Maximal oxygen uptake”[tiab] OR “Graded exercise test”[tiab] OR “Maximal test”[tiab] OR “VO2”[tiab] OR “VO2 max”[tiab] OR “VO2 peak”[tiab] #3 Review[ti] OR Cohort[ti] OR Meta-analysis[ti] OR Synthesis[ti] OR Consensus[ti] #1 AND #2 NOT #3
Lilacs	“water-based exercise” OR “water based” OR “water exercise” OR "water running" OR “water walking” OR “water cycling” OR “deep-water running” OR “deep water OR “water-based aerobic exercise” OR “water aerobic exercise” OR “aquatic exercise” OR “aquatic cycling” OR aquatic OR “underwater walking” OR “underwater gait” OR (water AND exercise)
Embase	#1 'water based exercise'/exp OR 'deep water running'/exp OR 'aquatic exercise'/exp OR 'aquatic exercise' OR 'exercise, aquatic' OR 'underwater exercise'/exp OR 'water-based exercis*':ti,ab OR 'water based':ti,ab OR 'aquatic exercis*':ti,ab OR 'head-out water-based':ti,ab OR 'water running':ti,ab OR 'water walking':ti,ab OR 'water cycling':ti,ab OR 'aquatic cycling':ti,ab OR 'deep water':ti,ab OR 'water-based aerobic exercise':ti,ab OR 'water aerobic exercis*':ti,ab OR 'underwater walking':ti,ab OR 'underwater gait':ti,ab OR aquajogging:ti,ab OR hydrogymnastic*:ti,ab OR 'water exercise':ti,ab OR 'water environment':ti,ab #2 'exercise test'/exp OR 'effort test' OR 'exercise test' OR 'exercise testing' OR 'stress test' OR 'test, exercise' OR 'cardiopulmonary exercise test'/exp OR 'cardiopulmonary exercise test' OR 'cardiorespiratory response'/exp OR 'exercise tolerance'/exp OR 'exercise tolerance' OR 'tolerance, exercise' OR 'exercise tolerance test'/exp OR 'oxygen consumption'/exp OR 'o2 consumption' OR 'o2 uptake' OR 'oxygen consumption' OR 'oxygen demand' OR 'oxygen intake' OR 'oxygen requirement' OR 'oxygen uptake' OR 'oxygen utilization' OR 'peak oxygen uptake'/exp OR 'maximal oxygen consumption'/exp OR 'maximal oxygen uptake'/exp OR 'graded exercise test'/exp OR 'exercise testing':ti,ab OR 'cardiorespiratory fitness'/exp OR 'cardiorespiratory fitness' OR 'cardiorespiratory respons*':ti,ab OR 'exercise capacity':ti,ab OR 'maximal incremental test':ti,ab OR 'oxygen uptake':ti,ab

	OR 'maximal test':ti,ab OR vo2:ti,ab #3 'review':ti OR 'meta analysis':ti OR 'consensus':ti #1 AND #2 NOT #3
SPORTDiscus	#1 “water-based exercis*” OR “water-based” OR “head-out water-based” OR "water running" OR “water walking” OR “water cycling” OR “aquatic cycling” OR “deep-water running” OR “water-based aerobic exercise” OR “underwater walking” OR “underwater gait” OR “aquajogging” OR “hydrogymnastics” OR "AQUATIC exercises" OR "WATER aerobics" OR "AQUATIC exercises -- Therapeutic use” OR aquatic OR “deep water” OR “water exercise” OR “water environment” OR “aquatic environment” #2 “Exercise testing” OR “Cardiopulmonary exercise test” OR “Cardiorespiratory response” OR “Exercise capacity” OR “Maximal incremental test” OR “Oxygen uptake” OR “Peak oxygen uptake” OR “Maximal oxygen consumption” OR “Maximal oxygen uptake” OR “Graded exercise test” OR “Maximal test” OR “Maximal incremental test” OR “VO2” OR “VO2 max” OR “VO2 peak” OR "EXERCISE tests" OR "EXERCISE tolerance" OR "AEROBIC capacity" OR "CARDIOPULMONARY fitness measurement" OR "CARDIOPULMONARY fitness" OR "OXYGEN consumption" #3 TI (Review OR Cohort OR Meta-analysis OR Synthesis OR Consensus) #1 AND #2 NOT #3

3.2.3 Processo de seleção

Todos os estudos encontrados foram importados para o software de gerenciamento de referência Endnote X8 e as duplicatas foram removidas. De acordo com os critérios de elegibilidade, dois revisores avaliaram independentemente os títulos e resumos dos estudos potenciais previamente pesquisados. Antes do processo de elegibilidade, foi realizada uma triagem piloto de 100 artigos para padronização. Divergências entre o par de revisores foram resolvidas por discussão ou decisão de um terceiro revisor. Todos os resumos que não forneceram informações suficientes sobre os critérios de inclusão e exclusão foram avaliados em texto completo.

3.2.4 Processo de coleta de dados

Todos os estudos que atenderam aos critérios de elegibilidade em nível de texto completo foram incluídos no processo de extração de dados. Os dados foram extraídos por um autor e depois confirmados por outro. As discordâncias foram resolvidas por discussão entre os revisores para concordar ou consultar um terceiro revisor independente. Uma planilha de dados codificada foi usada para extrair os resultados máximos e associados aos limiares anaeróbios de VO_2, FC e IEP (ou seja, VO_{2max}, VO_{2LA}, FC_{max}, FC_{LA}, IEP_{max} e IEP_{LA}) durante os testes incrementais aquáticos e terrestres. Além disso, as seguintes informações foram coletadas: autor, ano de publicação, periódico, características dos participantes (ou seja, tamanho da amostra, idade, sexo e características antropométricas) e protocolos de teste em água e terra (ou seja, exercícios, intensidade inicial, incrementos, tempo de cada etapa, critérios de término, profundidade da água, temperatura ambiente ou temperatura da água). Os autores dos estudos incluídos foram contatados quando algum dado não foi encontrado no texto completo.

3.2.5 Avaliação da qualidade metodológica dos estudos incluídos

A *Joanna Briggs Institute (JBI) Critical Appraisal tool for Analytical Cross-Sectional Studies* (MOOLA et al., 2017) foi adaptada para avaliar a qualidade metodológica dos estudos incluídos. A ferramenta é composta por oito perguntas com as seguintes respostas possíveis: Sim, Não, Não está claro ou Não/Aplicável. Os estudos foram classificados com base nos critérios fornecidos pela diretriz JBI (MOOLA et al., 2017). As questões 5 (isto é, os fatores de confusão foram identificados?) e 6 (isto é, as estratégias para lidar com os fatores de confusão foram declaradas?) não foram incluídas em nossa análise porque não são aplicadas ao desenho dos estudos incluídos. Como os mesmos participantes realizaram os protocolos, assumimos que não houve fatores de confusão intersujeitos. Além disso, foram incluídos dois itens considerados relevantes para a avaliação da qualidade dos estudos: (1) "O método de randomização foi descrito em detalhes?" e (2) "Foi descrito o tempo de intervalo entre os protocolos?".

A avaliação foi feita por pares de revisores de forma independente e com base nas informações relatadas no artigo publicado. Foi feito um teste piloto para consolidar os critérios de avaliação da equipe de revisores. As discrepâncias foram resolvidas por discussão entre os pares ou por consulta a todas as autoras. Não será gerado uma pontuação total para estudos, assim, a apresentação e discussão da classificação dos estudos serão baseadas nos itens individuais da ferramenta.

3.2.6 Métodos de síntese

Serão realizadas meta-análises de efeitos aleatórios para cada variável da revisão usando o software *Review Manager* (versão 5.4) quando dois ou mais estudos relatarem a mesma variável. Os dados brutos (ou seja, médias, desvio padrão e tamanho da amostra) serão extraídos e os estudos serão ponderados individualmente usando o método de variância inversa. A diferença média bruta (DM), com intervalo de confiança (IC) de 95%, será utilizada para meta-análise quando a mesma unidade de medida tiver sido utilizada entre estudos para um parâmetro individual. Quando diferentes unidades de medidas entre estudos tiverem sido utilizadas para um mesmo parâmetro individual, será utiliza a DM padronizada, com IC de 95%.

A heterogeneidade estatística será medida pelo teste qui-quadrado e pelo teste de inconsistência (I^2). A heterogeneidade será considerada significativa com base no valor $p < 0,10$ ou o valor $I^2 > 40\%$. Para variáveis com alta heterogeneidade, poderão ser realizadas análises de subgrupos de acordo com modalidades, características dos protocolos ou características dos participantes.

4. Cronograma

Ano	2021												2022											
Atividades/Mês	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Elaboração do projeto	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									
Revisão de literatura	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Qualificação do projeto															X									
Elaboração do manuscrito I	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
Submissão do manuscrito I																		X						
Registro da RS no PROSPERO																X								
Buscas nas bases de dados																X								
Seleção dos artigos																	X							
Extração dos dados																		X						
Análise do risco de viés																		X						
Análise dos dados																			X	X				
Discussão dos resultados																				X	X			
Elaboração do manuscrito II																						X	X	
Defesa da tese																								X
Entrega da versão final																								X

5. Divulgação dos resultados

Os resultados obtidos a partir do presente trabalho serão divulgados a partir da apresentação da tese necessária à obtenção do título de Doutora em Educação Física pelo Programa de Pós-Graduação em Educação Física da Universidade Federal de Pelotas, assim como da publicação de dois artigos a serem submetidos em periódicos de impacto internacional.

1) *Effects of aquatic aerobic training on physical fitness in young and older adults: a systematic review and meta-analysis*, a ser submetida ao *Journal of Strength and Conditioning Research.*
2) *Cardiorespiratory parameters comparison between incremental protocols performed in aquatic and land environments by healthy individuals: a systematic review and meta-analysis*, a ser submetida ao *Sports Medicine*.

Além disso, os resultados serão apresentados em postagens em redes sociais com interpretações dos resultados em linguagem acessível para o público leigo.

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RELATÓRIO DE ATIVIDADES

O presente relatório apresentará as atividades realizadas durante o curso de doutorado realizado na linha de pesquisa de Exercício físico para a promoção da saúde do Programa de Pós-Graduação em Educação Física da Universidade Federal de Pelotas.

O ingresso no curso de doutorado foi realizado com o projeto de pesquisa intitulado “Efeitos do treinamento aeróbio realizados em diferentes meios sobre a percepção de fadiga, aptidão física, saúde mental e qualidade de vida de mulheres sobreviventes do câncer de mama: um ensaio clínico randomizado”. No entanto, devido à pandemia de COVID-19, o desenvolvimento desse projeto foi comprometido. O objetivo era manter a ideia original do projeto uma vez que o mesmo foi agraciado no Edital Universal do CNPq e a prorrogação de seis meses do prazo do curso de doutorado foi aprovado pelo colegiado. Durante a espera do controle da pandemia e da liberação das atividades presenciais para o desenvolvimento do projeto foi realizada a escrita do artigo de protocolo do estudo.

No segundo semestre de 2021 reavaliamos a situação e percebemos que mesmo com a prorrogação de seis meses do prazo do curso de doutorado, o período restante não seria possível o desenvolvimento do trabalho como parte da tese de doutorado. Assim, elaborou-se um novo projeto de pesquisa intitulado “Treinamento aeróbio no meio aquático: efeitos crônicos na aptidão física e parâmetros de intensidade utilizados na prescrição de adultos e idosos”, composto por duas revisões sistemáticas, tendo em vista as restrições decorrentes da pandemia e a impossibilidade de coleta de dados dentro do prazo possível. Assim, em 28 de março de 2022 o novo projeto foi apresentado à banca de qualificação composta pela professora Ana Carolina Kanitz e pelo professor Rodrigo Suddatti Delevatti. Após a qualificação, uma das revisões que já estava em andamento foi concluída e publicada no periódico *Sports Medicine* e a elaboração da segunda revisão foi iniciada.

Além das atividades obrigatórias do curso de doutorado (integralização de 42 créditos em disciplinas e aprovação em dois testes de proficiência em língua estrangeira) e como bolsista (estágio de docência orientada e apresentação de pelo menos um trabalho em evento científico por ano), destacam-se outras atividades de caráter acadêmico realizadas durante o período do curso, listadas a seguir.

Participação em projetos de extensão:

1. Projeto de extensão Exercise Research in Cancer (ERICA) da Universidade Federal de Pelotas;
2. Projeto de extensão Mulheres em Ciências da Saúde da Universidade Federal do Rio Grande do Sul.

Participação em projetos de pesquisa:

1. Efeitos de dois volumes de treinamento combinado nas adaptações neuromusculares, cardiorrespiratórias e de qualidade de vida de mulheres que finalizaram o tratamento primário de câncer de mama;
2. Respostas de um programa de alongamento supervisionado remotamente durante pandemia por COVID-19 no quadro doloroso, depressão, sono e funcionalidade em mulheres com fibromialgia: um ensaio clínico randomizado;
3. Efeitos de 16 semanas de diferentes programas de treinamento no meio aquático sobre variáveis neuromusculares, cardiorrespiratórias, funcionais, de qualidade de vida e de função cognitiva em idosas: um ensaio clínico randomizado;
4. Análise de desempenho e recuperação de jogo simulado em atletas de futsal universitário;
5. Treino de potência em adultos de meia-idade, idosos saudáveis e com limitação na mobilidade: adaptações no sistema neuromuscular e seus efeitos sobre o desempenho funcional;
6. Efeitos de um programa de exercício físico supervisionado remotamente em indivíduos com diabetes tipo 2: um ensaio clínico randomizado;
7. Efeitos de um programa de exercício supervisionado remotamente sobre a percepção de fadiga de sobreviventes do câncer de mama: uma análise nos tempos da COVID-19;
8. *Hypertension Approaches in the Elderly: a Lifestyle study* (HAEL).

Coorientações de trabalhos de conclusões de curso:

1. Samara Nickel Rodrigues (2019) - Respostas agudas glicêmicas e pressóricas após diferentes modelos de treino aeróbio no meio aquático em pacientes com diabetes mellitus tipo 2;
2. Mariana Borba Gomes (2019) - Força de reação do solo vertical em exercício realizado nos meios aquático e terrestre por crianças com sobrepeso e obesidade;
3. Esther Gonçalves Meireles (2021) - Comparação de parâmetros cardiorrespiratórios, neuromusculares, percepção de fadiga e qualidade de vida entre os diferentes estadiamentos do câncer de mama.

Artigos publicados como primeira autora:

1. Andrade, L. S., Pinto, S. S., Silva, M. R., Schaun, G. Z., Portella, E. G., Nunes, G. N., David, G. B., Wilhelm, E. N., & Alberton, C. L. (2020). Water-based continuous and interval training in older women: Cardiorespiratory and neuromuscular outcomes (WATER study). *Experimental Gerontology*, *134*, 110914. https://doi.org/10.1016/j.exger.2020.110914

2. Andrade, L. S., Pinto, S. S., Silva, M. R., Campelo, P. C., Rodrigues, S. N., Gomes, M. B., Krüger, V. L., de Ferreira, G. F., & Alberton, C. L. (2020). Randomized clinical trial of water-based aerobic training in older women (WATER Study): functional capacity and quality of life outcomes. *Journal of Physical Activity & Health*, 1–9. https://doi.org/10.1123/jpah.2019-0552

3. Andrade, L. S., Kanitz, A. C., Häfele, M. S., Schaun, G. Z., Pinto, S. S., & Alberton, C. L. (2020). Relationship between oxygen uptake, heart rate, and perceived effort in an aquatic incremental test in older women. *International Journal of Environmental Research and Public Health*, *17*(22), 8324. https://doi.org/10.3390/ijerph17228324

4. Andrade, L. S., Häfele, M. S., Schaun, G. Z., Rodrigues, M. N., Gomes, M. B., David, G. B., Pinto, S. S., & Alberton, C. L. (2020). Ponto de deflexão da frequência cardíaca como método não invasivo para determinar o limiar anaeróbio no meio aquático em idosas treinadas. *Revista Brasileira de Fisiologia do Exercício*, 19(6), 468-477. https://doi.org/10.33233/rbfex.v19i6.4202

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6. Andrade, L. S., David, G. B., Wilhelm, E. N., Pinto, S. S., & Alberton, C. L. (2022). Effect of high intensity interval treadmill exercise on subsequent lower and upper limb strength performance. *Research Quarterly for Exercise and Sport*, 1–8. https://doi.org/10.1080/02701367.2021.1948954

7. Andrade, L. S., Botton, C. E., David, G. B., Pinto, S. S., Häfele, M. S., & Alberton, C. L. (2022). Cardiorespiratory parameters comparison between incremental protocols performed in aquatic and land environments by healthy individuals: a systematic review and meta-analysis. *Sports Medicine,* https://doi.org/10.1007/s40279-022-01687-y

Artigos publicados como colaboradora:

1. Alberton, C. L., Bgeginski, R., Pinto, S. S., Nunes, G. N., Andrade, L. S., Brasil, B., & Domingues, M. R. (2019). Water-based exercises in pregnancy: Apparent weight in immersion and ground reaction force at third trimester. *Clinical Biomechanics (Bristol, Avon)*, *67*, 148–152. https://doi.org/10.1016/j.clinbiomech.2019.05.021

2. Terres, N. C., Andrade, L. S., & Alberton, C. L. (2019). Comportamento de variáveis fisiológicas durante a realização de exercícios sobre o mini trampolim em diferentes cadências. *Revista Brasileira de Prescrição e Fisiologia do Exercício*, 13(81), 17-27.

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10. Häfele, M. S., Alberton, C. L., Häfele, V., Schaun, G. Z., Nunes, G. N., Calonego, C., Castro, T. F., Andrade, L. S., & Pinto, S. S. (2022). Water-based training programs improve functional capacity, cognitive and hemodynamic outcomes? the ACTIVE randomized clinical trial. *Research Quarterly for Exercise and Sport*, 1–11. https://doi.org/10.1080/02701367.2021.1935433

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ARTIGO 1

Artigo intitulado “**Effects of aquatic aerobic training on physical fitness in young and older adults: a systematic review and meta-analysis**” a ser submetido ao *Journal of Strength and Conditioning Research*.

EFFECTS OF AQUATIC AEROBIC TRAINING ON PHYSICAL FITNESS IN YOUNG AND OLDER ADULTS: A SYSTEMATIC REVIEW WITH META-ANALYSIS

Running head: Aquatic aerobic exercise and physical fitness

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ABSTRACT

The effects of exclusively aerobic training in the aquatic environment on the different components of physical fitness still need to be clarified in the literature. The study aimed to investigate the effects of aquatic aerobic training on the physical fitness of young and older adults. PubMed, LILACS, and EMBASE were searched in April 2022. Eligibility criteria included randomized and non-randomized trials with aerobic training programs performed by young and older adults analyzing components of physical fitness (i.e., cardiorespiratory capacity, muscle strength, balance, and flexibility). Meta-analyses compared aquatic aerobic training and 1) control, 2) land aerobic training, and 3) aquatic combined training. Twenty-one studies were included in the review and 15 in the meta-analysis. All studies included in the meta-analysis had a sample of older adults. Compared with the control, the results showed a significant increase in cardiorespiratory capacity after 8 to 24 weeks of training programs. In the maximum muscular strength, increments were observed in programs of 10 to 12 weeks, while in the strength related to functionality, improvements were observed in programs of up to 8 months. No difference was observed for agility/dynamic balance and flexibility. Similar responses in cardiorespiratory capacity were observed in aquatic and land aerobic training programs. Furthermore, aerobic was superior to combined training in improving cardiorespiratory responses with similar muscle strength and agility/dynamic balance increases. In conclusion, in addition to improvements in cardiorespiratory parameters, the results showed that exclusively aerobic training in the aquatic environment promotes increased muscle strength in older adults.

Key words: water-based exercise; aquatic environment; cardiorespiratory fitness; muscle strength; balance; flexibility.

INTRODUCTION

Exercises performed in the aquatic environment in an upright position have gained popularity as an alternative to conventional physical activities performed on land (e.g., walking/running, cycling, or dancing), probably due to some advantages provided by the physical properties of water (60). As a reflection, the literature on aquatic exercises for health promotion has grown significantly and exponentially (64). Thus, the effects of training in the aquatic environment have been investigated since the 1990s, with most studies using combined or multi-component training programs (4,7,20,29,30,35,37,43,44,51,57,58,61). It is noteworthy that the adaptations provided by these training models are derived from both aerobic and other applied exercises, such as strength, balance, and flexibility.

Research on cardiorespiratory and neuromuscular adaptations of exclusively aerobic aquatic training has gained prominence, especially in the last decade (5,6,12,21,22,29,40,48,50,54). Regarding the chronic effects of performing exercises in the aquatic environment, aerobic training programs may have as an additional advantage the characteristics and adaptations of multi-component training (i.e., adaptations in three or more components of physical fitness) (12). Studies have shown that aerobic programs in the aquatic environment can generate, in addition to improvements in cardiorespiratory parameters, increments in other parameters of physical fitness, such as muscle strength (6,8,12,21,22,29,50,54), flexibility (8,48), and dynamic balance (8,48,54). Such additional adaptations can be attributed mainly to the overload imposed by the aquatic environment due to the drag force generated by the movement in the water and to the buoyancy that provides instability during exercises (60). In addition, it is important to mention that aerobic training was evidenced to be even more efficient than combined training (29) or strength training programs (12) to improve responses cardiorespiratory responses with similar increments in muscle strength responses.

In recent years, systematic reviews with meta-analyses have provided the scientific community with more consistent evidence on the effects of training programs in the aquatic environment on components of physical fitness in adults and the elderly (15,25,31,33,45,47,49,52,55,62). Reichert et al. (49) demonstrated that water-based exercise programs improve the functional capacity of older individuals. Likewise, Saquetto et al. (52) showed that aquatic training programs promote benefits in cardiorespiratory capacity, muscle strength, and flexibility compared to no intervention. Additionally, aquatic training has shown similar increments to land-based training to improve cardiorespiratory fitness, muscle strength, agility, and flexibility (52). It is essential to highlight that the conclusions of these studies were based on the grouping of different training models (i.e., aerobic, strength, combined, or multi-component) without subgroup analysis by type of exercise; therefore, information on specific adaptations of each model was not presented.

It should be stressed that aerobic exercises are especially recommended in exercise guidelines (11,19,42), mainly due to the benefits provided to the cardiovascular health of practitioners since the low cardiorespiratory fitness is a predictor of mortality from all causes and cardiovascular events (32). Thus, to the best of our knowledge, no systematic review of the current literature has investigated the adaptations of exclusively aerobic training programs in different modes of aquatic exercise performed in an upright position on different health-related components of physical fitness (i.e., cardiorespiratory capacity, muscle strength, balance, and flexibility). Summarizing the results of this topic can provide a better answer about the effectiveness of this model in different parameters of physical fitness of adults and older individuals to confirm if aquatic aerobic programs have characteristics and adaptations of multi-component training. Therefore, the purposes of the present review were the following: to investigate the effects of aerobic training programs in the aquatic environment on physical fitness components of young and older adults compared with their non-trained peers; to compare the effects of aerobic training programs in the aquatic environment compared with aerobic training programs performed in the land environment; to compare the effects of aerobic training programs in the aquatic environment compared with other training models (e.g., multi-component, combined, strength, balance, or flexibility) performed in the aquatic environment.

METHODS

Experimental Approach to the Problem

The present study is characterized as a systematic review with meta-analysis. The results of this meta-analysis may include a more precise estimate of the effect of aerobic exercise in the aquatic environment on the components of physical fitness (i.e., cardiorespiratory capacity, muscle strength, balance, and flexibility). A systematic review with a meta-analysis was conducted and reported according to the Cochrane Handbook for Systematic Reviews of Interventions (24) and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (36,39). This study was registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD42022330641).

Eligibility Criteria

Eligibility criteria were defined by the PICOS strategy (i.e., participants, intervention, comparator, outcome, and study design). In addition, the studies were limited to Portuguese, English, and Spanish and those published in peer-reviewed journals.

Participants: Women and men aged 18 and over, with no upper age limit or fitness level. Studies that assumed cardiovascular, osteoarticular, neuromuscular diseases, cancers, disabilities, and/or post-surgical recovery as inclusion criteria were not included.

Interventions: Aerobic training programs in different modes of aquatic exercise performed in an upright position, with a minimum duration of eight weeks, without restriction on the maximum duration, frequency, session duration, intensity, or devices.

Comparators: 1) control group (e.g., no exercise; sham; non-periodized activities; health education); 2) aerobic training programs performed in the land environment; 3) any other training model (i.e., multi-component, combined, strength, balance, or flexibility) performed in the aquatic environment; 4) studies without any comparator group also were included and presented only in the qualitative synthesis.

Outcomes: To comprehensively account for physical fitness measurements, any of the following outcomes were considered for inclusion in the meta-analysis. For cardiorespiratory fitness, parameters evaluated by maximum oxygen consumption (VO_{2max}) or performance in functional tests were included (e.g., walk or step up tests). For muscle strength, performance in one-repetition maximum (1RM) or chair stand tests were included. For agility/dynamic balance, up-and-go and tandem-walking tests were included. Finally, for flexibility, reaching tests were included. For qualitative synthesis, studies with any measure of cardiorespiratory capacity, muscle strength, balance, or flexibility were included.

Study design: Randomized or non-randomized trials.

Information sources

Searches were performed on April 28, 2022, in three electronic databases for full-text indexed publications (i.e., PubMed, LILACS, and EMBASE). The search period was from the earliest manuscript available until April 2022. Studies were limited to Portuguese, English, and Spanish languages and published in peer-reviewed journals. In addition, the reference lists of the articles found were manually checked. The full search strategies per database are presented in Supplemental Digital Content 1.

Selection Process

All retrieved reports were imported for the Rayyan app (38), and duplicates were removed. Afterward, the titles and abstracts of potential studies were evaluated in duplicate by independent reviewers (LSA and SNR / LSA and MTC) according to the eligibility criteria. A pilot screening of 100 articles was carried out to standardize the eligibility process. Any disagreements were solved by discussion. Abstracts that did not provide sufficient information about the inclusion and exclusion criteria were evaluated in full text. Finally, full texts were evaluated in duplicate independently (LSA and SNR). Disagreements were resolved by personal discussion between the reviewers to agree or consult with a third independent reviewer (CLA).

Data Collection Process

A coded data sheet was used to extract the data of interest to the study. The variables related to cardiorespiratory capacity, muscle strength, balance, and flexibility before and after interventions with aerobic training programs in the aquatic environment and their respective comparator groups were collected. In addition, the following information was collected: publication information (i.e., authors, year of publication, journal, and country), participants' characteristics (i.e., sample size, age, sex, anthropometric characteristics, and level of training), characteristics of training programs (i.e., modality/exercises, program duration, frequency, intensity prescription parameter, intensity, session duration). Figure data were extracted using the WebPlotDigitizer software (version 4.6, Pacifica, CA, USA). The data extraction process was conducted in duplicate by independent reviewers (LSA and SNR). Disagreements were resolved by personal discussion between the reviewers to reach an agreement. Authors were contacted when any data was not found in the full text.

Study Quality Assessment

The methodological quality of the studies was assessed by the Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX) (56), specifically designed for use in physical training studies. TESTEX is a 15-point scale (5 points for study quality and 10 points for reporting), in which the evaluators assigned each point as '1' or '0'. The scale uses 12 criteria, with some criteria scoring more than one possible point for a maximum score of 15 points. The study quality criteria are: 1) Eligibility criteria specified; 2) Randomization specified; 3) Allocation concealment; 4) Groups similar at baseline; 5) Blinding of assessor (for at least one key outcome); while the criteria for the study reporting are: 6) Outcome measures assessed in 85% of patients; 7) Intention-to-treat analysis; 8) Between-group statistical comparisons reported; 9) Point measures and measures of variability for all reported outcome measures; 10) Activity monitoring in control groups; 11) Relative exercise intensity remained constant; 12) Exercise volume and energy expenditure.

Two reviewers (LSA and MTC) independently assessed the quality of each of the studies. Before the beginning of the evaluation process, a pilot test was carried out to consolidate and clarify the instrument classification criteria among the reviewers. Disagreements were resolved with discussion.

Synthesis Methods

A separate meta-analysis for each review variable was performed using the Review Manager software (version 5.4) when two or more studies reported the same outcome. The effect measures were obtained through the mean, standard deviation, and sample size. Meta-analyses were performed comparing 1) aquatic aerobic training and control groups; 2) aquatic and land aerobic training; and 3) aerobic and combined aquatic training. Studies were individually weighted using the inverse variance method under a random-effects model to generate effect estimates.

Three studies presented a control period (5,6,29); thus, their data were included in the meta-analyses that compared aquatic aerobic training programs versus control. In addition, for the study by Kanitz et al. (29), oxygen consumption at the second ventilatory threshold (VO_{2VT2}) was considered the cardiorespiratory outcome because it was the value available as a control. On the other hand, Silva et al. (54) and Häfele et al. (22) had the same participants, so data from only one of them were included in the meta-analyses comparing aerobic and combined training programs for cardiorespiratory and muscle strength outcomes. Thus, the data from the study by Häfele et al. (22) were chosen because they presented the outcomes closest to the gold standard. For studies that presented more than one aerobic training program (5,6,16), groups were treated as individual studies, and the sample of the comparator groups was divided.

The mean difference (MD) with 95% confidence intervals (CI) was used for meta-analyses when the included studies reported the results of the variables using the same measurement scale. At the same time, the standardized MD (SMD) with 95% CI was calculated for variables that use different measures. Statistical heterogeneity was measured by the χ^2 and inconsistency (I^2) tests. Heterogeneity was considered significant based on p-measured value < 0.10 or I^2 value > 40%. Sensitivity analyzes were performed from the withdrawal of studies one by one to try to reduce heterogeneity. With the withdrawals from Bocalini et al. (8, 9), a significant reduction in heterogeneity was observed. Thus, the exclusion of these studies was carried out considering the discrepancy between the characteristics of the aerobic programs and the other studies since only the studies by Bocalini et al. (8,9) used upper and lower limb devices (i.e., soft-cushioned hand-bars, leg pads, and aquatubes) during exercise. In contrast, the others used only the overload of the environment (i.e., water).

RESULTS

Study Selection

The initial search included 2393 articles, and hand searches included three articles. After removing 825 duplicates, 1571 titles and abstracts were read, of which 1530 were not eligible. Of these, 40 full-text articles were evaluated for eligibility, of which 19 were excluded (i.e., one for the type of study and 18 for the training characteristics), resulting in 21 studies included in the qualitative synthesis and 15 in the quantitative synthesis (meta-analysis). Of the six studies that were not included in the quantitative analysis, four were due to not presenting any comparator groups (46,48,53,59) and two due to the strength and balance outcomes (26,63) defined in the inclusion criteria. A flow diagram of the review process is in Figure 1.

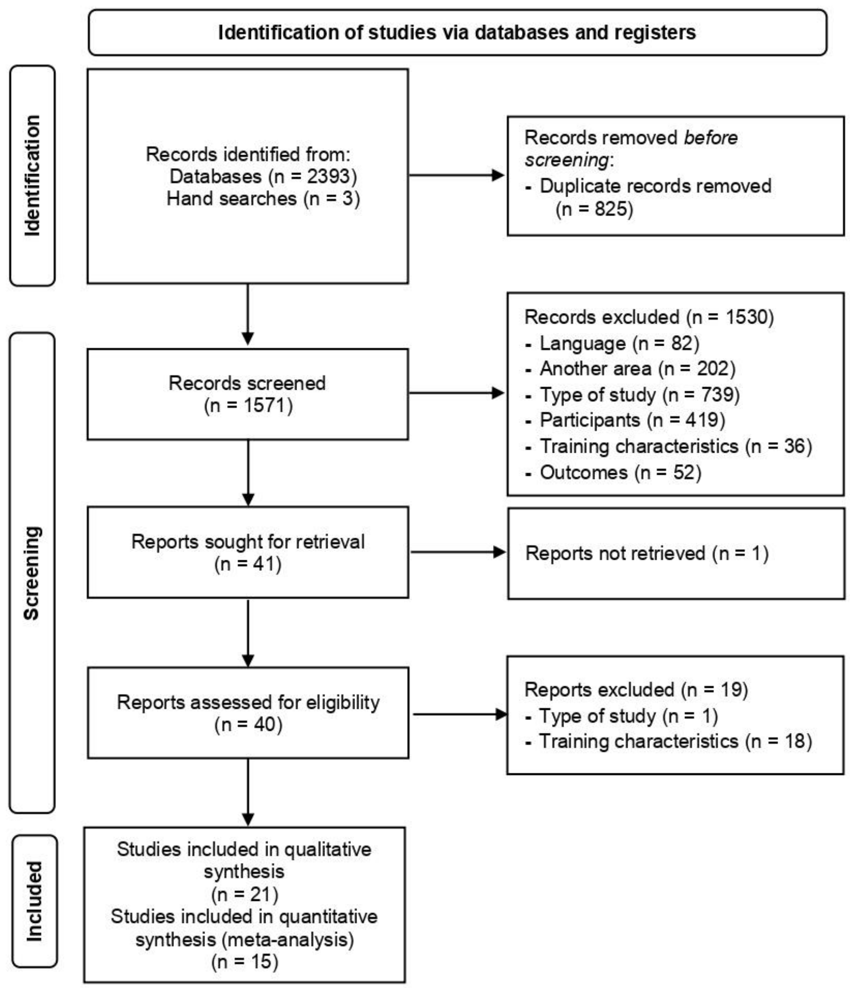

Figure 1. Flowchart of the article selection process.

Study characteristics

A summary of the characteristics of the included studies is shown in Table 1. Included studies were from Brazil (5,6,8,9,12,21,22,29,41,48,53,54), Sweden (10), Portugal (16), Australia (23), Iran (26), Japan (28), Mexico (34), Canada (59), USA (63), and Italy (46).

Table 1. Characteristics of the included studies.

Study	Sample	Intervention	Outcomes: Cardiorespiratory	Outcomes: Muscle strength	Outcomes: Balance / Agility	Outcomes: Flexibility	Main Findings
Andrade et al. (6)	**N:** 41 **Sex:** Female **Age:** 64.3 ± 3.1 years	Continuous Training x Interval Training	VO_{2peak}; VO_{2VT}; VO_{2VT2}; HR_{rest}; Time to exhaustion.	Knee extension 1RM; Knee extension DME.	-	-	Both training programs resulted in similar increases in cardiorespiratory capacity and lower limb muscle strength.
Andrade et al. (5)	**N:** 41 **Sex:** Female **Age:** 64.3 ± 3.1 years	Continuous Training x Interval Training	6-min walk	30-s chair stand	Timed up-and-go	-	Both training programs resulted in similar increases in cardiorespiratory capacity and lower limb muscle strength. No difference was observed for agility.
Bocalini et al. (8)	**N:** 72 **Sex:** Female **Age:** 63.7 ± 1.1 years*	Aquatic Training x Land Training x Control	VO_{2max}	Arm curl; 30-s chair stand.	8-foot up-and-go	Chair sit-and-reach; Back scratch;	Both aquatic and land training programs improved cardiorespiratory fitness, lower limb strength and flexibility, and agility, with greater increases in cardiorespiratory fitness and lower limb strength and flexibility for aquatic training. In addition, only the aquatic training program improved upper limb strength and flexibility. No change was observed for the control

							group.
Bocalini et al. (9)	**N:** 50 **Sex:** Female **Age:** > 62 years	Aquatic Training X Control	VO_{2max}; 800-m walk.	Arm curl; 30-s chair stand.	8-foot up-and-go; Standing up on just one leg without hopping.	Chair sit-and-reach	The aquatic training program improved cardiorespiratory capacity, muscle strength of upper and lower limbs, balance, agility, and flexibility of lower limbs. No change was observed for the control group.
Broman et al. (10)	**N:** 29 **Sex:** Female **Age:** 69 ± 4 years	Aquatic Training x Control	$VO_{2max;}$ Work rate; Ventilatory volume; HR_{max}; Respiratory exchange ratio.	-	-	-	The aquatic interval training program improved cardiorespiratory fitness parameters. No change was observed for the control group.
Costa et al. (12)	**N:** 69 **Sex:** Female **Age:** 66.1 ± 5.9 years*	Aerobic Training x Resistance Training x Control (non-periodic water-based exercise program)	VO_{2peak}; VO_{2VT2}; Time to Exhaustion; HR_{rest}; HR_{VT2}; HR_{peak}.	Knee extensors and flexors 1RM; Shoulder horizontal flexors 1RM.	-	-	The aerobic training program is more efficient for improving cardiorespiratory responses than the resistance training. Both training programs resulted in similar increases in lower limb muscle strength. The control group only improved some cardiorespiratory and strength parameters.
Farinha et al. (16)	**N:** 152 **Sex:** Female	Continuous Training x Interval Training x	2-min step	Arm curl; 30-s chair	Timed up-and-go	Chair sit-and-	Both aerobic training programs increased

	and Male **Age:** 72.3 ± 5.2 years (n = 92)*	Combined Training x Control		stand; Hand grip.		reach; Back scratch.	cardiorespiratory fitness and lower and upper limb muscle strength, while the combined training program only increased lower limb muscle strength. Neither training program improved agility and lower and upper limb flexibility. No change was observed for the control group.
Häfele et al. (22)	**N:** 41 **Sex:** Female **Age:** Age: 65 ± 4 years	Aerobic Training x Combined Training x Control (non-periodized dance or gymnastics classes on land).	VO_{2peak}; VO_{2VT1}; $VO_{2VT2.}$	Knee extensors 1RM; Horizontal chest press 1RM	-	-	Both aquatic training programs and control on land improved cardiorespiratory capacity; however, only aquatic training programs enhanced the strength of the lower limbs.
Häfele et al. (21)	**N:** 52 **Sex:** Female **Age:** 66.2 ± 4.0 years	Aerobic Training x Aerobic + Combined Training x Control (therapeutic aquatic sessions)	6-min walk; $HR_{rest.}$	30-s chair stand	8-foot up and go	Chair sit-and-reach	Both aquatic training programs and therapeutic exercises improved cardiorespiratory capacity and lower limb strength, with no change in agility and lower limb flexibility.
Haynes et al. (23)	**N:** 40 **Sex:** Female and Male **Age:** 62.5 ± 6.8 years (n = 71)*	Aquatic Training x Land Training x Control (seminars)	VO_{2max}; HR_{max}; Time to exhaustio n.	-	-	-	Both aquatic and land training programs showed similar improvements in cardiorespiratory capacity. No change was observed for the control group.
Irandoust et	**N:** 40	Aquatic Training x	-	-	Tinetti	-	Both training programs

al. (26)	**Sex:** Female and Male **Age:** 65 ± 4.9 years	Land Training x Aquatic Control x Land Control			Performance Oriented Mobility Assessment		revealed improvement in balance compared to controls, with no difference between them.
Kaneda et al. (28)	**N:** 46 **Sex:** Female and Male **Age**: 60.7 ± 4.1 years (n = 30)	Normal water exercise (water walking, water-resistance training using a kickboard, and other water-walking exercises) x Deep water running	-	-	Postural-sway distance; Postural-sway area; Tandem-walking time.	-	Both training programs improved different aspects of balance. Normal Water Exercise improved postural-sway area and Deep Water Running improved postural-sway distance and tandem walking.
Kanitz et al. (29)	**N:** 34 **Sex:** Male **Age:** 65.2 ± 3.8 years	Aerobic Training x Combined Training	VO_{2peak} VO_{2VT2} HR_{rest}	Knee extensors and flexors 1RM; Knee extensors and flexors DME;	-	-	Both training programs improved cardiorespiratory capacity and muscle strength. Aerobic training was more efficient in improving cardiorespiratory fitness than combined training, with similar increments in muscle strength responses.
Martínez et al. (34)	**N:** 26 **Sex:** Female **Age:** 67.5 ± 5.0 years*	Aquatic Training x Control	-	Lifting from the sitting position (GDLAM protocol)	Lifting the chair and walk by the house (GDLAM protocol)	-	The aquatic aerobic training program improved functional autonomy (i.e., the General GDLAM index). No change was observed for the control.
Pernambuco	**N:** 84	Aquatic Training x	-	Lifting	Lifting the	-	The aquatic aerobic

et al. (41)	**Sex:** Female **Age:** 66.9 ± 3.7 years*	Control		from the sitting position (GDLAM protocol)	chair and walk by the house (GDLAM protocol)		training program improved agility and functional autonomy (i.e., the general GDLAM index). No change was observed for the control group.
Raffaelli et al. (46)	**N:** 34 **Sex:** Female **Age:** 26.4 ± 3.8 years	Aquatic Training (A single group)	VO_{2max} - estimated based on the step test.	Leg-curl 1 RM; Leg-extension 1 RM; Pectoral machine 1RM; Sit-up DME; Push-up DME.	Flamingo balance	Sit-and-reach Back stretch	The aquatic aerobic training program improved cardiorespiratory capacity, muscle strength, and balance, with no change in upper and lower limb flexibility.
Reichert et al. (48)	**N:** 36 **Sex:** Female and Male **Age:** 67.9 ± 5.5 years (n = 25)*	Continuous Training x Interval Training	6-min walk	Arm curl; 30-s chair stand.	8-foot up and go	Chair sit-and-reach; Back scratch.	Both aquatic training programs resulted in similar increases in cardiorespiratory capacity, upper and lower limb muscle strength, agility/dynamic balance, and lower limb flexibility, with no change in upper limb flexibility.
Silva et al. (54)	**N:** 41 **Sex:** Female **Age:** 65 ± 4 years	Aerobic Training x Combined Training x Control (non-periodized dance or gymnastics classes on land).	6-min walk	30-s chair stand	8-foot up and go	-	Both aquatic training programs and control on land improved cardiorespiratory capacity, lower limb strength, and

							agility/dynamic balance.
Silva et al. (53)	**N:** 40 **Sex:** Female and Male **Age:** 58.5 ± 7.8 years (n = 36)*	Depression group x Non-depression group	-	-	Timed up-and-go; Berg balance scale.	Chair sit-and-reach	The aquatic exercise program did not change the balance, agility, and flexibility in the non-depression group after the intervention.
Tenorio & Loureda (59)	**N:** 8 **Sex:** Female and Male **Age:** 25-40 years	Aquatic Training (A single group)	Maximum aerobic speed; Test duration.	-	-	-	The aquatic aerobic training program promoted in maximum aerobic speed and test duration increases in seven of the eight individuals studied.
White & Smith (63)	**N:** 18 **Sex:** Female and Male **Age:** 28.7 ± 5.4 years*	Aquatic Training x Control	-	Peak torque of knee and elbow extensors and flexors; Peak torque of shoulder adductors and abductors.	-	-	The aquatic aerobic training program improved lower and upper limb muscle strength. No change was observed for the control.

* Indicates that a weighted average was performed with the age data available in the article; DME = dynamic muscular endurance; GDLAM = Group of Latin American Development for the Maturity; HR_{max} = maximal heart rate; HR_{rest} = resting heart rate; VO_{2max} = maximal oxygen uptake; VO_{2peak} = peak oxygen uptake; VO_{2VT1} = oxygen uptake in the first ventilatory threshold; VO_{2VT2} = oxygen uptake in the second ventilatory threshold; 1RM = one-repetition maximum.

Of the 20 studies, 12 studies included only female participants (5,6,8-10,12,21,22,34,41,46,54), one study included only male participants (29), and eight studies had both (16,23,26,28,48,53,59,63). The sample of studies consisted of older adults for most of the studies (5,6,8-10,12,16,21-23,26,28,29,34,41,48,53,54) or young adults (46,59,63)

Regarding the comparator groups, 11 studies had control groups; of these, seven had traditional control groups with no exercise (8–10,16,34,41,63). In the study by Haynes et al. (23), participants in the control group attended the university to participate in seminars unrelated to physical activity or health promotion once every six weeks. The study by Irandoust et al. (26) was composed of two control groups, the aquatic control group sat by the pool and talked to each other, and the land control group sat on chairs near the gym and talked to each other. Four studies had active control groups; in three studies, the participants performed non-periodized activities in the aquatic (12) or land environment (22,54), and in one study, control participants performed therapeutic sessions in the aquatic environment (21). In addition, three studies had a control period (5,6,29).

Three studies presented exercise comparator groups in the land environment (8,23,26). Six studies presented comparator groups of different training models in the aquatic environment; of these, five were combined training programs (16,22,28,29,54) and one resistance training program (12). Additionally, four studies compared continuous and interval aerobic training programs in the aquatic environment (5,6,16,48). The study by Silva et al. (53) was composed of a group of depressive and another of non-depressive individuals, with only the non-depressive group being included in the qualitative synthesis. Finally, two studies presented a single group (46,59).

Of the 20 studies, 15 measured cardiorespiratory fitness; of these, eight by maximum incremental tests with oxygen consumption (6,8–10,12,22,23,29), and seven by functional tests (5,9,16,21,46,48,54). In addition, Tenorio & Loureda (59) study evaluated the cardiorespiratory capacity from a maximal indirect test.

Fifteen studies measured muscle strength; five used 1RM tests (6,12,22,29,46), three used dynamic muscular endurance tests (6,29,46), and one evaluated concentric peak torque (63). Seven studies measured lower limb strength by 30-s chair stand tests (5,8,9,16,21,48,54), two studies by 5-chair stand tests (34,41), and four measured upper limb strength by 30-s arm curl tests (8,9,16,48). Additionally, Farinha et al. (16) evaluated handgrip strength.

Balance was assessed in 13 studies. Eleven studies measured agility/dynamic balance, eight by Timed Up and Go or 8-Foot Up and Go tests (5,8,9,16,21,48,53,54), two by agility test of GDLAM protocol (34,41) and one by tandem walking test (28). Additionally, three studies assessed static balance using postural sway tests (28) or participants' ability to stand on one leg (9,46). Furthermore, Irandoust et al. (26) assessed balance with the help of the instrument Tinetti Performance Oriented Mobility Assessment, while Silva et al. (53) used the Berg Balance Scale.

Flexibility was assessed in seven studies, all of which measured lower limb flexibility (8,9,16,21,46,48,53) and four also measured upper limb flexibility (8,16,46,48).

Table 2 presents the characteristics of the aquatic aerobic training programs. Regarding the mode of exercise, 13 studies comprised water-based exercises in shallow pool (5,6, 8,9,12,16,21,22,41,46,53,54,63), four studies deep water running (10,29,48,59), and one study water walking (23). In addition, one study combined walking and water-based exercises in a shallow pool (26), one study combined water walking and deep water running (28), and one did not specify the exercises performed (34).

Table 2. Characteristics of the aquatic aerobic training programs.

Study	Mode of exercise	Volume	Intensity
Andrade et al. (5,6)	Water-based exercises in shallow pool	**Duration:** 12 weeks **Frequency:** 2 times per week **Session duration:** 44 min (4 min – warm-up, 36 min – main part, 4 min – cool-down)	**Continuous:** Weeks 1-4 – RPE 13 Weeks 5-8 – RPE 14 Weeks 9-10 – RPE 15 Weeks 11-12 – RPE 16 **Interval:** Weeks 1-4 – 9 × (2 min RPE 16 + 2 min RPE 11) Weeks 5-8 – 12 × (1.5 min RPE 17 + 1.5 min RPE 11) Weeks 9-12 – 18 × (1 min RPE 18 + 1 min RPE 11)
Bocalini et al. (8,9)	Water-based exercises in shallow pool	**Duration:** 12 weeks **Frequency:** 3 times per week **Session duration:** 60 min (10 min – warm-up, 45 min – main part, 5 min – cool-down)	70% HR_{max} (age-predicted)
Broman et al. (10)	Deep water running	**Duration:** 8 weeks **Frequency:** 2 times per week **Session duration:** 48 min (7 min – warm-up, 30 min – main part, 7 – cool-down)	1st block: 2 × 3 min 75% HR_{max} + 2 min 80% HR_{max} + (40 s work:20 s rest) 2nd block: 2 × 3 min 75% HR_{max} + 2 min 85% HR_{max} + (20 s work:20 s rest) 3rd block: 3 × 1 min 75% HR_{max} + 2 min 85% HR_{max} + (15 s work:15 s rest)
Costa et al. (12)	Water-based exercises in shallow pool	**Duration:** 10 weeks **Frequency:** 2 times per week **Session duration:** 45 min (30 min – main part)	Weeks 1-5 – 6 × (4 min 90-95% HR_{AT} + 1 min 80-85% HR_{AT}) Weeks 6-10 – 6 × (4 min 95-100% HR_{AT} + 1 min 85-90% HR_{AT})
Farinha et al. (16)	Water-based exercises in shallow	**Duration:** 28 weeks **Frequency:** 2 times per	**Continuous:** 60-70% $HR_{max.}$ **Interval:** stimulus of 30 s at 70-80% HR_{max} +

	pool	week **Session duration:** 45 min (10-15 min – warm-up, 20-30 min – main part, 5-10 min – cool-down)	intervals of 1 min at 60-70% HR_{max}.
Häfele et al. (22) Silva et al. (54)	Water-based exercises in shallow pool	**Duration:** 12 weeks **Frequency:** 2 times per week **Session duration:** 24-27 min – main part	Weeks 1-3 – 85-90% HR_{AT} Weeks 4-6 – 90-95% HR_{AT} Weeks 7-9 – 95-100% HR_{AT} Weeks 10-12 – 12 × (1 min 105-110% HR_{AT} + 1 min 80-85% HR_{AT})
Häfele et al. (21)	Water-based exercises in shallow pool	**Duration:** 16 weeks **Frequency:** 2 times per week **Session duration:** ≅ 45 min (5 min – warm-up, 36 min – main part, 5 min – cool-down)	Weeks 1–2 – 80–85% HR_{AT} Weeks 3–4 – 85–90% HR_{AT} Weeks 5–7 – 90–95% HR_{AT} Weeks 8–10 – 95–100% HR_{AT} Weeks 11–13 – 2 min 100–105% HR_{AT} + 1 min RPE 13 Weeks 14–16 – 2 min 105–110% HR_{AT} + 1 min RPE 13.
Haynes et al. (23)	Walking in shallow pool	**Duration:** 24 weeks **Frequency:** 3 times per week **Session duration:** 15-50 min.	15 min of exercise at 40%-45% HR_{res}, building to 50 min at 55%-65% HR_{res} over the course of the study, with 1 interval and 2 continuous exercise sessions per week.
Irandoust et al. (26)	Walking and water-based exercises in shallow pool	**Duration:** 8 weeks **Frequency:** 3 times per week **Session duration:** 50 min (10 min – warm-up, 30 min – main part, 10 min – cool-down)	Weeks 1-4 – 50% HR_{max} Weeks 5-8 – 60% HR_{max}
Kaneda et al. (28)	Water walking and deep water running	**Duration:** 12 weeks **Frequency:** 2 times per week	NR

		Session duration: 80 min (10 min – warm-up on land; 20 min – water walking exercise; 30 min – deep water running, 10 min – rest on land; and 10 min – recreation and relaxation in the water)	
Kanitz et al. (29)	Deep water running	**Duration:** 12 weeks **Frequency:** 3 times per week **Session duration:** 45 min (30 min – main part)	Weeks 1–4 – 6 × (4 min 85–90% HR_{AT} + 1 min < 85% HR_{AT}) Weeks 5–8 – 6 × (4 min 90–95% HR_{AT} + 1 min < 85% HR_{AT}) Weeks 9–12 – 6 × (4 min 95–100% HR_{AT} + 1 min < 85% HR_{AT})
Martínez et al. (34)	Not specified	**Duration:** 12 weeks **Frequency:** 5 times per week **Session duration:** 50 min (10 min – warm-up, 30 min – main part, 10 min – cool-down	Weeks 1-6 – 40-50% HR_{res} Weeks 7-12 – 50-60% $HR_{res.}$
Pernambuco et al. (41)	Water-based exercises in shallow pool	**Duration:** 8 months **Frequency:** 2 times per week **Session duration:** 50 min (five phases of 7 min – main part, 5 min – cool down)	NR
Raffaelli et al. (46)	Water-based exercises in shallow pool	**Duration:** 9 weeks **Frequency:** 2 times per week **Session duration:** 45 min (10 min – warm-up, 30 min – main part, 5 min – cool-down)	Weeks 1-2 – intensity "moderate" (i.e., musical cadence at 110-120 bpm; 120-130 bpm; 130-140 bpm) Weeks 3-5 – intensity "moderate" to "hard" (i.e., musical cadence at 120-130 bpm; 130-140 bpm) Weeks 6-9 – intensity ''hard'' (i.e., musical cadence at 130-140 bpm).

Reichert et al. (48)	Deep water running	**Duration:** 28 weeks **Frequency:** 2 times per week **Session duration:** 45 min (5 min – warm-up; 30-36 min - main part, 4-10 min cool-down)	**Continuous:** Weeks 1-4 – RPE 13 Weeks 5-8 – RPE 15 Weeks 9-12 – RPE 16 Weeks 12-16 – RPE 13 Weeks 17-20 – RPE 15 Weeks 21-24 – RPE 16 Weeks 25-28 – RPE 17 **Interval:** Weeks 1-4 – 10 × (2 min RPE 15 + 1 min RPE 11) Weeks 5-8 – 6 × (4 min RPE 17 + 1 min RPE 11) Weeks 9-12 – 7 × (4 min RPE 17 + 30 s RPE 11) Weeks 12-16 – 10 × (2 min RPE 15 + 1 min RPE 11) Weeks 17-20 – 6 × (4 min RPE 17 + 1 min RPE 11) Weeks 21-24 – 7 × (4 min RPE 17 + 30 s RPE 11) Weeks 25-28 – 12 × (2 min RPE 18 + 1 min RPE 15)
Silva et al. (53)	Water-based exercises in shallow pool	**Duration:** 12 weeks **Frequency:** 2 times per week **Session duration:** 45 min (5 min – warm-up, 40 min – main part, 5 min – cool-down)	50% – 60% HR_{max} or a Borg scale score of 13 to 14 points – 36 × (30 s with 10 s intervals)
Tenorio & Loureda (59)	Deep water running	**Duration:** 8 weeks **Frequency:** 3 times per week **Session duration:** 19-48 min	First session of the week: sets (i.e., 7-16 sets throughout training) of 1 min at 85% HR_{max} + 1 min at 50% HR_{max} Second session of the week: sets (i.e., 4-9 sets throughout training) 2 min at 80% HR_{max} + 2 min at 50% HR_{max} Third session of the week: (i.e., 3-7 sets throughout training) 3 min at 75% HR_{max} + 3 min at 50% HR_{max}
White & Smith (63)	Water-based exercises in shallow	**Duration:** 8 weeks	70-75% HR_{res}

pool	**Frequency:** 3 times per week **Session duration:** 50 min (5 min – warm-up, 40 min – main part, 5 min – cool-down)	

bpm = beats per minute; HR_{AT} = heart rate in the anaerobic threshold; HR_{max} = maximal heart rate; HR_{res} = reserve heart rate; NR = non reported; RPE = rating of perceived exertion.

The duration of the programs ranged from 8 weeks (10,26,59,63) to 8 months (41), with most studies lasting 12 weeks (5,6,8,9,22,28,29,34,53,54). Regarding frequency, most studies had two weekly sessions (5,6,10,12,16,21,22,28,41,46,48,53,54), seven studies had three weekly sessions (8,9,23,26,29,59,63), and one had five weekly sessions (34). Regarding the session duration, most studies had sessions between 45 to 60 min (5,6,8-10,12,16,21,26,29,34,41,46,48,53,63).

Concerning intensity prescription parameters, 13 studies used the heart rate (HR). Six of them used percentages of the HR_{max} (8–10,16,26,59), three used percentages of the reserve HR (HR_{res}) (23,34,63), and four percentages of the HR in the anaerobic threshold (HR_{AT}) (12,22,29,54). Two studies used HR and rating of perceived exertion (RPE) together: Häfele et al. (21) used $\%HR_{AT}$, and Silva et al. (53) $\%HR_{max}$. In addition, RPE was the parameter used in three studies (5,6,48). Still, one study used musical cadence (46), and two did not report whether there was intensity control (28,41).

Aquatic Aerobic Training *versus* Control

Forest plots of the comparison between aquatic aerobic training programs and control for cardiorespiratory fitness are shown in Figure 2. Eight studies measured cardiorespiratory capacity by VO_{2max} (6,8–10,12,22,23,29), and the pooled results demonstrated that aquatic aerobic training programs significantly increase VO_{2max} (MD = 5.18 $ml.kg^{-1}.min^{-1}$; 95% CI 2.51 to 7.85; see Figure 1, Supplemental Digital Content 2) compared to control groups. However, a high heterogeneity between studies was found ($p < 0.001$; $I^2 = 91\%$). Based on the sensitivity analysis, the studies by Bocalini et al.

(8,9) seem to be a source of heterogeneity, thus removing these studies nullified the heterogeneity (p = 0.58; I^2 = 0%), maintaining the significant effect in favor of aquatic aerobic training (MD: 3.32 $ml.kg^{-1}.min^{-1}$; CI 95% 2.48 to 4.16; Figure 2A). Five studies measured cardiorespiratory capacity by functional tests (5,9,16,21,54), and the pooled results showed an effect in favor of aquatic aerobic training (SMD = 0.45; 95% CI 0.04 to 0.86; p for heterogeneity = 0.11; I^2 = 42%; see Figure 1, Supplemental Digital Content 2) compared to control groups. However, with the removal of the study by Bocalini et al. (9), this improvement in cardiorespiratory capacity became non-significant (SMD: 0.27; 95% IC -0.08 to 0.62; p for heterogeneity = 0.58; I^2 = 0%; Figure 2B).

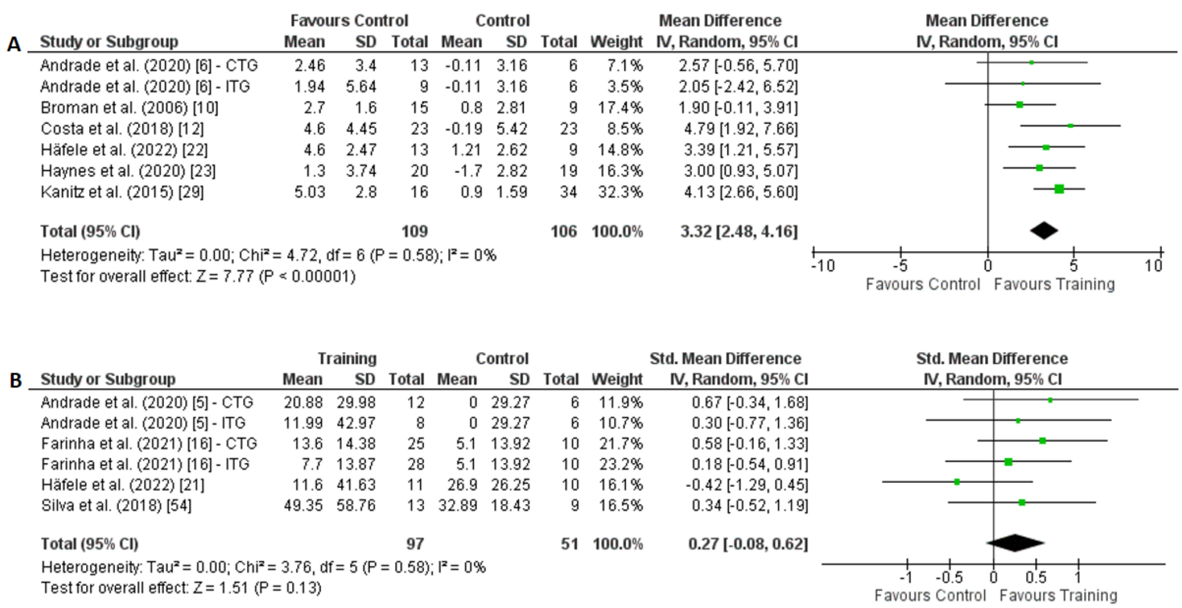

Figure 2. Random effects meta-analysis comparing aquatic aerobic training programs and control groups on cardiorespiratory capacity by maximal oxygen uptake (A) and functional tests (B). SD = standard deviation; CTG = continuous training group; ITG = interval training group.

Forest plots of the comparison between aquatic aerobic training programs and control for muscle strength of lower limbs variables are shown in Figure 3. Four studies measured muscle strength by 1RM tests (Figure 3A) (6,12,22,29), and eight assessed muscle strength by functional tests (Figure 3B) (5,8,9,16,21,34,41,54). The pooled results showed that the aquatic aerobic training programs significantly increased the muscle strength evaluated by 1RM of knee extensors compared to the control (MD = 3.03 kg; 95% CI 1.62 to 4.44; p for heterogeneity = 0.34; I^2 = 11%; Figure 3). Regarding functional outcomes, the pooled results demonstrated increased muscle strength in lower limbs (SMD = 1.68; 95% CI 0.80 to 2.56; p for heterogeneity < 0.001; I^2 = 90%; see Figure 2, Supplemental Digital Content 2). Removing studies by Bocalini et al. (8,9), the heterogeneity became null (p = 0.74; I^2 = 0%), maintaining the effects in favor of aquatic aerobic training on muscle strength (SMD: 0.79; 95% CI 0.51 to 1.06; Figure 3B).

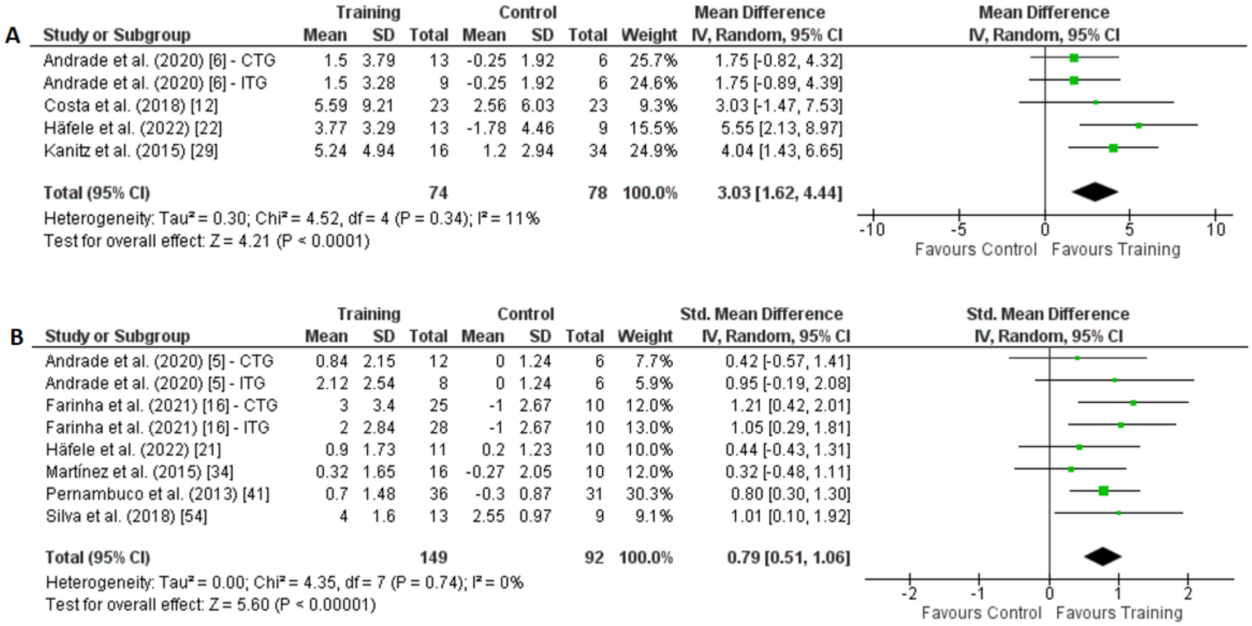

Figure 3. Random effects meta-analysis comparing aquatic aerobic training programs and control groups on the muscle strength of lower limbs measured by one-repetition maximum test (A) and functional tests (B). SD = standard deviation; CTG = continuous training group; ITG = interval training group.

There were not enough studies to perform meta-analyses for the static balance variable. For agility/dynamic balance, the meta-analysis comparing aerobic training programs and control included eight studies (5,8,9,16,21,34,41,54). Pooled results demonstrated improvement in agility/dynamic balance in the training group compared to the control group (SMD = 0.63 seconds; 95% CI 0.11 to 1.16; p for heterogeneity < 0.001; I^2 = 77%; see Figure 3, Supplemental Digital Content 2). Removing studies by Bocalini et al. (8,9), the heterogeneity has become moderate; however, this agility/dynamic balance improvement became non-significant. (SMD: 0.34; CI 95% -0.04 to 0.72; p for heterogeneity = 0.08; I^2 = 45%; Figure 4).

Study or Subgroup	Training Mean	Training SD	Training Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Andrade et al. (2020) [5] - CTG	0.08	0.76	12	-0.23	0.25	6	9.6%	0.46 [-0.54, 1.45]
Andrade et al. (2020) [5] - ITG	-0.04	0.88	8	-0.23	0.25	6	8.7%	0.26 [-0.81, 1.32]
Farinha et al. (2021) [16] - CTG	0.2	0.86	25	0.2	0.54	10	13.7%	0.00 [-0.73, 0.73]
Farinha et al. (2021) [16] - ITG	0	1.71	28	0.2	0.54	10	13.9%	-0.13 [-0.85, 0.59]
Häfele et al. (2022) [21]	0	0.76	11	0	0.16	10	11.6%	0.00 [-0.86, 0.86]
Martínez et al. (2015) [34]	1.19	6.41	16	-1.16	2.56	10	12.5%	0.43 [-0.37, 1.23]
Pernambuco et al. (2013) [41]	3.7	4.93	36	-0.7	1.13	31	18.4%	1.18 [0.65, 1.70]
Silva et al. (2018) [54]	0.68	0.6	13	0.57	0.43	9	11.6%	0.20 [-0.66, 1.05]
Total (95% CI)			**149**			**92**	**100.0%**	**0.34 [-0.04, 0.72]**

Heterogeneity: Tau² = 0.13; Chi² = 12.82, df = 7 (P = 0.08); I² = 45%
Test for overall effect: Z = 1.77 (P = 0.08)

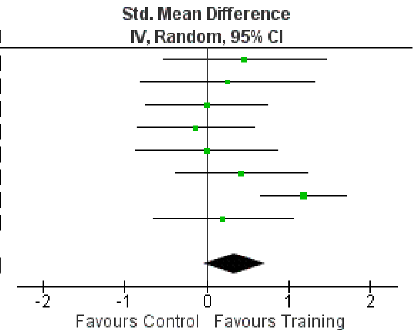

Figure 4. Random effects meta-analysis comparing aquatic aerobic training programs and control groups on agility/dynamic balance. SD = standard deviation; CTG = continuous training group; ITG = interval training group.

For flexibility, the meta-analysis comparing aerobic training programs and control included four studies (8,9,16,21). The pooled results showed no difference between aquatic aerobic training and control for the lower limb flexibility (MD = 3.39 cm; 95% CI -1.22 to 8.00; p for heterogeneity < 0.001; I^2 = 95%; see Figure 4, Supplemental Digital Content 2). Removing the studies by Bocalini et al. (8,9), the heterogeneity became moderate (p = 0.09; I^2 = 58%), maintaining the same result without difference between aerobic training and control (MD: -0.48 cm; 95% IC -4.50 to 3.54; Figure 5).

Study or Subgroup	Training Mean	Training SD	Training Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Farinha et al. (2021) [16] - CTG	1.7	3.85	25	0	6.18	10	35.8%	1.70 [-2.42, 5.82]
Farinha et al. (2021) [16] - ITG	1.2	4.4	28	0	6.18	10	35.5%	1.20 [-2.96, 5.36]
Häfele et al. (2022) [21]	-1.1	3.51	11	4.2	7.89	10	28.7%	-5.30 [-10.61, 0.01]
Total (95% CI)			**64**			**30**	**100.0%**	**-0.48 [-4.50, 3.54]**

Heterogeneity: Tau² = 7.33; Chi² = 4.79, df = 2 (P = 0.09); I² = 58%
Test for overall effect: Z = 0.24 (P = 0.81)

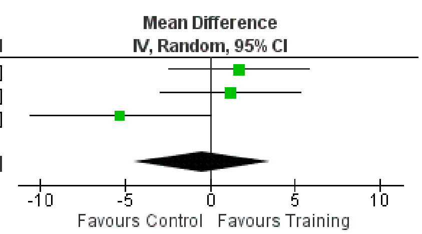

Figure 5. Random effects meta-analysis comparing aquatic aerobic training programs and control groups on the flexibility of lower limbs. SD = standard deviation; CTG = continuous training group; ITG = interval training group.

Aquatic Aerobic Training *versus* Land Aerobic Training

A Forest plot of the comparison between aquatic and land aerobic training programs for cardiorespiratory fitness is shown in Figure 6. Two studies compared gains in cardiorespiratory capacity between aerobic training programs in water versus on land (8,23). Pooled results indicated no difference between aerobic training programs performed in water and on land (MD: 3.23 ml.kg^{-1}.min^{-1}; 95% CI -2.45 to 8.91), with substantial heterogeneity ($p < 0.001$; $I^2 = 91\%$). An insufficient number of studies were included to perform meta-analyses comparing aquatic and land training programs for strength, balance, and flexibility variables.

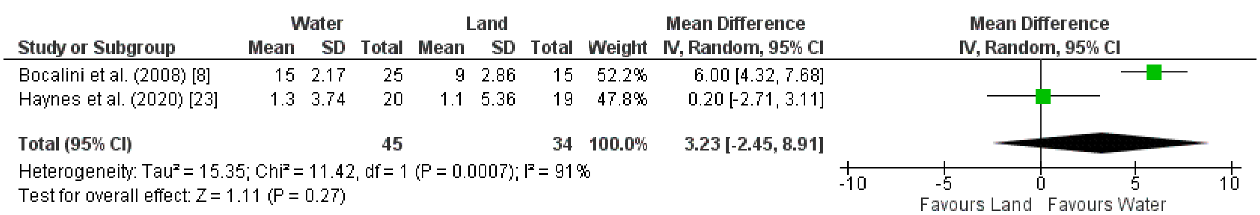

Figure 6. Random effects meta-analysis comparing aquatic and land aerobic training programs on cardiorespiratory capacity. SD = standard deviation.

Aquatic Aerobic Training *versus* Combined Aquatic Training

Six studies compared aerobic training programs with different training models in the aquatic environment. Five studies used combined training (16,22,28,29,54) and another one used resistance training (12). Therefore, it was possible to perform meta-analyses only comparing aerobic and combined training programs. Forest plots of the comparison between aerobic and combined training programs for cardiorespiratory fitness, muscle strength, and agility/dynamic balance variables are shown in Figure 7. Three studies measured cardiorespiratory capacity by comparing aerobic versus combined training programs (16,22,29). Pooled results indicated that aerobic-only training programs showed more significant increments than combined training programs (SMD: 0.58; 95% CI 0.15 to 1.01), with non-significant heterogeneity ($p = 0.20$; $I^2 = 36\%$). The same three studies were included in the meta-analysis of lower limb muscle strength (16,22,29); on the other hand, the pooled results showed no difference between the aerobic and combined training models for this variable (SMD: -0.04; 95% CI -0.38 to 0.30; p for heterogeneity = 0.57; $I^2 = 0\%$). Concerning agility/dynamic balance, three studies were included in the meta-analysis (16,28,54), and no difference was demonstrated between the aerobic and combined training models (SMD = 0.17; CI 95% -0.18 to 0.51; p for heterogeneity = 0.86; $I^2 = 0\%$). There were not enough studies to perform meta-analyses to compare aerobic and combined training programs for the static balance and flexibility variables.

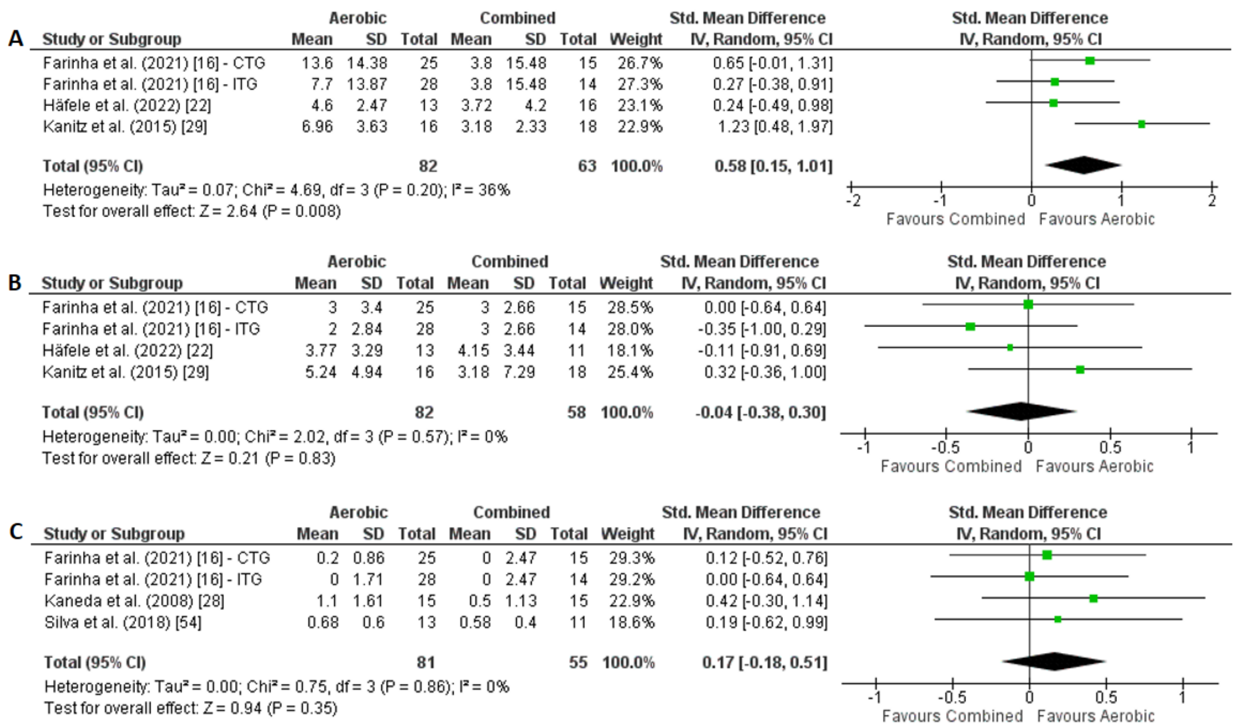

Figure 7. Random effects meta-analysis comparing aerobic and combined aquatic training programs on cardiorespiratory capacity (A), muscle strength of lower limbs (B), and agility/dynamic balance (C). SD = standard deviation; CTG = continuous training group; ITG = interval training group.

Study Quality Assessment

Table 3 presents the quality of the included studies. Of the total of 15 possible points on the TESTEX scale, the quality of the studies ranged from 3 to 13 points. Item 10 evaluated the monitoring of activities in control groups; thus, in those studies in which the comparator groups were composed of other types of control besides the traditional one without exercise, this criterion was considered not applicable.

Table 3 Study quality assessment according to TESTEX scale.

Study	C1	C2	C3	C4	C5	C6*	C7	C8**	C9	C10	C11	C12	Overall
Andrade et al. (6)	1	1	1	1	1	2	1	2	1	NA	1	1	13
Andrade et al. (5)	1	1	1	1	1	2	1	2	1	NA	1	1	13
Bocalini et al. (8)	1	0	0	1	0	1	0	2	1	0	0	1	7
Bocalini et al. (9)	1	0	0	1	0	2	0	2	1	0	0	0	7
Broman et al. (10)	1	0	0	0	0	3	0	2	1	0	0	1	8
Costa et al. (12)	1	1	1	1	1	2	1	2	1	NA	1	1	13
Farinha et al. (16)	1	1	1	1	1	1	0	2	1	0	0	1	10
Häfele et al. (22)	1	0	0	1	1	1	0	2	1	NA	1	1	9
Häfele et al. (21)	1	1	1	1	1	2	1	2	1	NA	1	1	13
Haynes et al. (23)	1	0	0	1	0	1	1	2	1	1	1	1	10
Irandoust et al. (26)	1	0	0	1	0	1	0	2	0	0	1	1	7
Kaneda et al. (28)	1	0	0	1	0	1	0	2	1	NA	0	0	6
Kanitz et al. (29)	1	1	1	1	1	1	0	2	1	NA	1	1	11
Martínez et al. (34)	1	0	0	1	0	0	0	2	1	0	1	0	6
Pernambuco et al. (41)	1	1	0	1	0	1	0	2	1	0	0	0	7
Raffaelli et al. (46)	1	0	0	0	0	2	0	0	1	NA	1	1	6

Reichert et al. (48)	1	0	0	1	0	0	0	2	1	NA	1	1	7
Silva et al. (54)	1	0	0	1	1	1	0	2	1	NA	1	1	9
Silva et al. (53)	1	0	0	0	0	0	0	0	1	NA	0	1	3
Tenorio & Loureda (59)	1	0	0	0	0	0	0	0	0	NA	1	1	3
White & Smith (63)	1	0	0	1	0	0	0	2	1	0	0	1	6

TESTEX = Tool for the assEssment of Study qualiTy and reporting in Exercise; C1 = Eligibility criteria specified; C2 = Randomization specified; C3 = Allocation concealment; C4 = Groups similar at baseline; C5 = Blinding of assessor; C6 = Outcome measures assessed in 85% of patients - *three points are possible: one point if adherence >85%, one point if adverse events are reported, and one point if exercise attendance is reported; C7 = 'Intention-to-treat' analysis; C8 = Reporting of between-group statistical comparisons - **two points are possible: one point if the primary outcome is reported and one point if secondary outcomes are reported; C9 = Point measures and measures of variability for all reported outcome measures; C10 = Activity monitoring in control groups; C11 = Relative exercise intensity remained constant; C12 = Exercise volume characteristics and energy expenditure; NA = not applicable.

DISCUSSION

This systematic review with meta-analysis summarizes the effects of aquatic aerobic training on the physical capacity outcomes of young and older adults. Most studies included in the systematic review had a sample of older adults. In turn, the performed meta-analyses exclusively included studies with this population; therefore, our results are more widely generalizable to adults over 60. According to our results, aquatic aerobic training programs were superior to control (i.e., no exercise; sham; non-periodized activities; health education) in improving cardiorespiratory capacity and muscle strength, with no difference in agility/dynamic balance and flexibility. In addition, similar responses in cardiorespiratory capacity were observed in aquatic aerobic training programs compared to land programs. Regarding comparing aerobic and combined training programs, aerobic training was superior to combined training in improving cardiorespiratory responses, with similar increments in lower limb muscle strength and agility/dynamic balance.

Our findings demonstrate that cardiorespiratory fitness, as measured by VO_{2max}, can be improved after aquatic aerobic training programs. We observed in the present synthesis an MD of 3.32 $ml.kg^{-1}.min^{-1}$ after aquatic training programs of 8 to 24 weeks compared to control. On the other hand, the improvement in cardiorespiratory capacity measured by functional tests was not significant. This result can be attributed to the fact that two studies included in the analysis of functional tests had control groups composed of non-periodized (54) and therapeutic exercises (21) that also positively affected cardiorespiratory capacity. In addition, the number of studies included in the meta-analysis for VO_{2max} was greater than for functional outcomes, and VO_{2max} can be considered the closest outcome to the gold standard. Therefore, we consider aerobic training programs in the aquatic environment effective in improving cardiorespiratory capacity. Thus, the present findings may reflect great clinical benefits, considering that low cardiorespiratory fitness has been explored as a predictor of all-cause mortality and cardiovascular events in healthy men and women (17,18).

In the comparison between aquatic and land training programs, the results demonstrated similar gains in cardiorespiratory capacity. This is an important finding of the present study, as it indicates that training programs in the aquatic environment can be as effective as aerobic training programs in the land environment in improving cardiorespiratory capacity. Therefore, the practitioner benefits from the positive effects of physical exercise in an environment with greater osteoarticular safety (1,2), a characteristic that favors adherence to aquatic exercise programs for older individuals or those with some difficulty performing exercises on land.

The findings related to comparing aerobic and combined training programs demonstrated that aerobic training was superior to combined training in improving cardiorespiratory responses. It is important to analyze some characteristics of the training programs included in the meta-analysis that may explain such findings. Two of the included studies had resistance exercises performed before aerobic exercises in combined training programs (22,29), which may have caused residual fatigue in the muscles involved during the resistance exercises and subsequently impaired the aerobic part performance. In the third included study (16), although aerobic exercises were performed before strength exercises in combined training, the total time of aerobic and combined training sessions was equalized. Thus, the aerobic group remained twice as long in aerobic exercises as the combined group (i.e., aerobic groups = 30 min of aerobic exercise; combined group = 15 min of aerobic exercise and 15 min of resistance exercises). Additionally, it is noteworthy that aquatic resistance programs alone are not efficient in improving cardiorespiratory capacity (12).

As we expected, in addition to improvements in cardiorespiratory parameters, the results of the present study demonstrated that aquatic aerobic exercises promote increases in muscle strength both in studies whose measurement was performed by 1RM or functional tests. We observed in the present synthesis a MD of 3.03 kg after aquatic training programs of 10 to 12 weeks. Regarding the functional results, we observed a SMD of 0.79 in chair stand tests after training programs 12 weeks to 8 months. The increase in muscle strength after aquatic training, even with specific aerobic prescription and goals, can be attributed mainly to the overload imposed by the aquatic environment due to the drag force generated by movement in the water (60). It is worth mentioning here the factors that influence the drag force (Fd) from the general fluid equation, i.e., $Fd = 0.5 \cdot Cd \cdot \rho \cdot A \cdot V^2$, where Cd is the drag coefficient, ρ is the fluid density, A is the projected area, and V is the velocity of movement (3). It is observed that the velocity of movement strongly influences the drag force provided by the water since it is squared and directly proportional to it. Therefore, aerobic exercises adequately prescribed can generate enough stimulus to increase muscle strength. This characteristic is important, as age-related progressive loss of strength and muscle mass is associated with many adverse outcomes, including falls, disability, and mortality (13,27). In addition, we emphasize that aerobic training programs in the aquatic environment encompass guidelines for older adults that suggest training programs that mainly include exercises focused on cardiorespiratory capacity and muscle strength (11). Thus, we emphasize that the increase observed in the maximum lower limb strength of the older adults was evident in the first weeks of training (i.e., up to 12 weeks), while the improvement in lower limb strength related to functionality was observed in programs from 12 weeks to up to 8 months.

The meta-analysis comparing aerobic and combined training programs demonstrated similar gains in lower limb muscle strength in older adults. In the study by Farinha et al. (16), the training programs were carried out for 28 weeks, with the duration of the sessions equalized (i.e., both aerobic and combined sessions lasted 30 min). In turn, the studies by Häfele et al. (22), Kanitz et al. (29), and Silva et al. (54) also showed similar increases in muscle strength after 12 weeks of aerobic and combined training, with the aerobic component equal in both groups and additional blocks of resistance exercises in the combined group. Additionally, Häfele et al. (21) demonstrated similar effects on muscle strength after 16 weeks of aerobic training compared to a program of eight weeks of aerobic exercise followed by eight weeks of combined training. Therefore, the findings of the present review point to relevant practical implications since aerobic training is sufficient to increase muscle strength and the most indicated to obtain the best cardiorespiratory results, at least at the beginning of the training program. In addition, aquatic aerobic training can be considered time efficient compared to combined training by dispensing with specific blocks of resistance exercises.

The findings of the current review demonstrated that aquatic aerobic training programs were not able to generate a significant increase in agility/dynamic balance compared to the control. Our results are similar to those of the meta-analysis of Saquetto et al. (52), who also did not observe a significant increase in agility in response to aquatic training in postmenopausal women. In disagreement, the results of other meta-analyses observed an increase in agility after aquatic training programs (15,49,62). These divergences may be related to the exercises used in the training programs since the results of these meta-analyses were based on grouping different training models in which they may have included a variety of exercises (i.e., exercises of the upper and lower limbs for strength, endurance, balance, and flexibility, and different modes of exercises such as water-based exercises, walking, and deep water running). It is important to emphasize training principles, especially concerning the concept of specificity. A training program that aims to increase balance must incorporate exercises that simulate and provide a challenge for the successful performance of the task in question (14). Thus, some exercises used in the training programs of the included studies may not provide enough stimulus to improve agility/dynamic balance.

Regarding the comparison between aerobic and combined training programs, the results of the meta-analysis showed no difference between the training models; however, it should be noted that the three studies included (16,28,54) showed conflicting results. Silva et al. (54) observed improvements in agility/dynamic balance after 12 weeks of both training groups (i.e., aerobic and combined). While in the study by Farinha et al. (16), none of the three training groups (i.e., continuous, interval, and combined) showed change after 28 weeks. In turn, Kaneda et al. (28) found an increase in the dynamic balance after aerobic training (i.e., a deep water running group - which consisted of water walking and deep water running), with no differences in the combined training (i.e., normal aquatic exercise group - which consisted of water walking, water-resistance training using a kickboard, and other water-walking exercises).

In addition, it is essential to consider the findings of some studies included only in the qualitative synthesis of the review. Reichert et al. (48) demonstrated improvement in agility/dynamic balance after continuous and interval training programs using deep water running. The improvement in body balance after deep water running training programs can be provided due to the instability during the exercises since the subjects do not have contact with the bottom of the pool. Regarding exercises in shallow water, there are still divergences in the responses of these programs, with some findings revealing improvement (8,9,41,46,54), while others demonstrate maintenance of balance ability (5,16,21,53). These divergences can be attributed to the different exercises performed in the training programs (e.g., running, kicking, sliding) that provide different levels of instability, as well as participants' training status related to balance at the baseline of the intervention.

The results of the meta-analysis on the flexibility of the lower limbs showed no difference between the aquatic aerobic training and the control. From the qualitative synthesis of the review, three studies showed improvement in flexibility after aerobic exercise programs (8,9,48). It is noteworthy that although none of these studies had specific flexibility exercises in the main part of the training, they all had stretching exercises as a warm-up or cool-down. In contrast, four studies showed no difference after the aerobic training program (16,21,46,53); of these, two did not incorporate stretching exercises into the relaxation training sessions (46,53). It is observed that there is a disagreement about the effects of aerobic training programs on lower limb flexibility. However, the improvement seen by some studies could be attributed to the stretching exercises used as a warm-up or cool-down and was not just a result of the aerobic exercises used in the main part of the training and the water characteristics.

Our study is not free of limitations. In addition to not including gray literature, our eligibility had language restrictions. We emphasize it was impossible to perform meta-analyses comparing results for strength, balance, and flexibility between aquatic and land training programs and the flexibility between aerobic and combined training programs. Likewise, not enough studies were found to perform meta-analyses, including young adults. Considering that research on the cardiorespiratory and neuromuscular effects of exclusively aerobic aquatic training gained emphasis only in the last decade, this indicates a gap in the literature yet to be filled with original studies.

PRACTICAL APPLICATIONS

Most studies included in this systematic review had a sample of older adults; thus, the meta-analyses carried out only included studies with this population. The results of the meta-analyses indicate that aquatic aerobic exercises efficiently improve cardiorespiratory capacity and muscle strength in older adults. Increases in cardiorespiratory capacity were observed in training programs of 8 to 24 weeks. Regarding lower limb muscle strength, the observed increase in maximal strength was evident in the first weeks of training (i.e., 10 to 12 weeks), while the improvement in strength measured by functional tests was observed in programs from 12 weeks to 8 months. However, no significant differences were observed for agility/dynamic balance and flexibility. The results also demonstrated that aerobic training programs in the aquatic environment can be as effective as land-based training programs in improving cardiorespiratory capacity. Furthermore, aerobic training was superior to combined training in improving cardiorespiratory responses with similar increments in lower limb muscle strength and agility/dynamic balance. From the qualitative synthesis of the review, it was possible to observe that aquatic aerobic training programs can also improve young adults' cardiorespiratory capacity and muscular strength. In addition, divergences were observed regarding the effects of aerobic training programs on agility/dynamic balance in older adults.

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Supplemental Digital Content 1

Effects of Aquatic Aerobic Training on Physical Fitness in Young and Older Adults: A Systematic Review with Meta-Analysis. Journal of Strength and Conditioning Research.
Luana S. Andrade; Cíntia E. Botton; Maurício T. X. Carvalho; Samara N. Rodrigues; Cristine L. Alberton. Corresponding author: andradelu94@gmail.com; Neuromuscular Assessment Laboratory, Physical Education School, Federal University of Pelotas, Pelotas, RS, Brazil.

Table 1 – Complete database search strategy.

Database	Search Strategy
PubMed	#1 “water-based exercis*”[tiab] OR “aquatic exercis*”[tiab] OR “head-out water-based”[tiab] OR "water running"[tiab] OR “water walking”[tiab] OR “water cycling”[tiab] OR “aquatic cycling”[tiab] OR “deep-water running”[tiab] OR “water-based aerobic exercise”[tiab] OR “water aerobic exercis*”[tiab] OR “underwater walking”[tiab] OR “underwater gait”[tiab] OR “aquajogging”[tiab] OR “hydrogymnastic*”[tiab] OR “water exercise”[tiab] #2 Review[ti] OR Cohort[ti] OR Cross-sectional[ti] OR Observational[ti] OR Case-control[ti] OR "Case report"[ti] OR Meta-analysis[ti] OR Synthesis[ti] OR Consensus[ti] #1 NOT #2
Lilacs	“water-based exercise” OR “water exercise” OR "water running" OR “water walking” OR “water cycling” OR “deep-water running” OR “deep water OR “water-based aerobic exercise” OR “water aerobic exercise” OR “aquatic exercise” OR “aquatic cycling” OR “underwater walking” OR “underwater gait” OR (water AND exercise)
Embase	#1 'water based exercise'/exp OR 'deep water running'/exp OR 'aquatic exercise'/exp OR 'aquatic exercise' OR 'exercise, aquatic' OR 'underwater exercise'/exp OR 'water-based exercis*':ti,ab OR 'aquatic exercis*':ti,ab OR 'head-out water-based':ti,ab OR 'water running':ti,ab OR 'water walking':ti,ab OR 'water cycling':ti,ab OR 'aquatic cycling':ti,ab OR 'water-based aerobic exercise':ti,ab OR 'water aerobic exercis*':ti,ab OR 'underwater walking':ti,ab OR 'underwater gait':ti,ab OR aquajogging:ti,ab OR hydrogymnastic*:ti,ab OR 'water exercise':ti,ab #2 'review':ti OR 'cohort':ti OR 'cross-sectional':ti OR 'observational':ti OR 'case-control':ti OR 'case report':ti OR 'meta analysis':ti OR 'synthesis':ti OR 'consensus':ti #1 NOT #2

Supplemental Digital Content 2

Effects of Aquatic Aerobic Training on Physical Fitness in Young and Older Adults: A Systematic Review with Meta-Analysis. Journal of Strength and Conditioning Research. Luana S. Andrade; Cíntia E. Botton; Maurício T. X. Carvalho; Samara N. Rodrigues; Cristine L. Alberton. Corresponding author: andradelu94@gmail.com; Neuromuscular Assessment Laboratory, Physical Education School, Federal University of Pelotas, Pelotas, RS, Brazil.

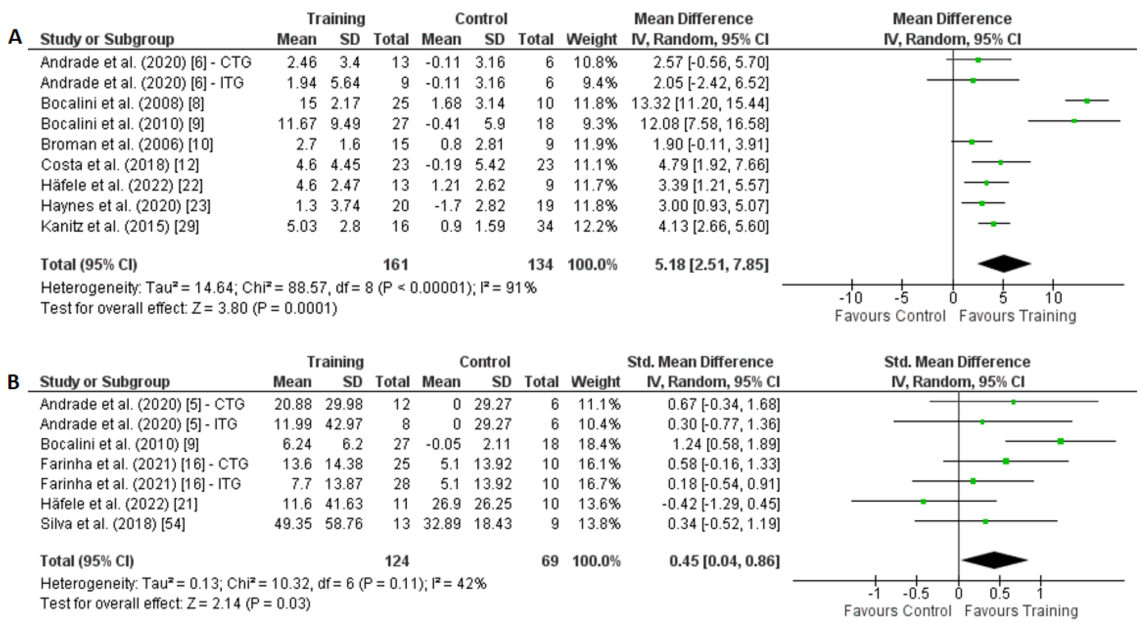

Figure 1. Random effects meta-analysis comparing aquatic aerobic training programs and control groups on cardiorespiratory capacity by maximal oxygen uptake (A) and functional tests (B). SD = standard deviation; CTG = continuous training group; ITG = interval training group.

Study or Subgroup	Training Mean	Training SD	Training Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Andrade et al. (2020) [5] - CTG	0.84	2.15	12	0	1.24	6	10.1%	0.42 [-0.57, 1.41]
Andrade et al. (2020) [5] - ITG	2.12	2.54	8	0	1.24	6	9.7%	0.95 [-0.19, 2.08]
Bocalini et al. (2008) [8]	13	2.13	25	1	1.27	10	8.1%	6.06 [4.39, 7.74]
Bocalini et al. (2010) [9]	9.9	1.77	27	0.1	1.17	18	8.7%	6.17 [4.71, 7.63]
Farinha et al. (2021) [16] - CTG	3	3.4	25	-1	2.67	10	10.5%	1.21 [0.42, 2.01]
Farinha et al. (2021) [16] - ITG	2	2.84	28	-1	2.67	10	10.6%	1.05 [0.29, 1.81]
Häfele et al. (2022) [21]	0.9	1.73	11	0.2	1.23	10	10.4%	0.44 [-0.43, 1.31]
Martínez et al. (2015) [34]	0.32	1.65	16	-0.27	2.05	10	10.5%	0.32 [-0.48, 1.11]
Pernambuco et al. (2013) [41]	0.7	1.48	36	-0.3	0.87	31	11.1%	0.80 [0.30, 1.30]
Silva et al. (2018) [54]	4	1.6	13	2.55	0.97	9	10.3%	1.01 [0.10, 1.92]
Total (95% CI)			**201**			**120**	**100.0%**	**1.68 [0.80, 2.56]**

Heterogeneity: Tau² = 1.75; Chi² = 89.21, df = 9 (P < 0.00001); I² = 90%

Test for overall effect: Z = 3.74 (P = 0.0002)

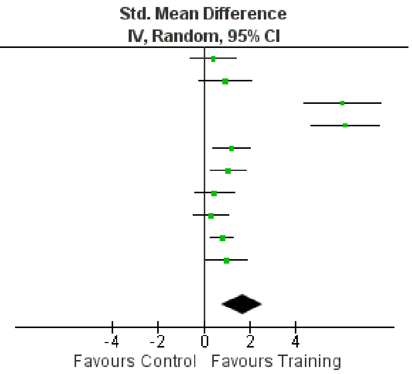

Figure 2. Random effects meta-analysis comparing aquatic aerobic training programs and control groups on the muscular strength of lower limbs measured by functional tests (B). SD = standard deviation; CTG = continuous training group; ITG = interval training group.

Study or Subgroup	Training Mean	Training SD	Training Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Andrade et al. (2020) [5] - CTG	0.08	0.76	12	-0.23	0.25	6	9.0%	0.46 [-0.54, 1.45]
Andrade et al. (2020) [5] - ITG	-0.04	0.88	8	-0.23	0.25	6	8.6%	0.26 [-0.81, 1.32]
Bocalini et al. (2008) [8]	2.9	1.82	25	1	0.36	10	10.2%	1.19 [0.40, 1.98]
Bocalini et al. (2010) [9]	5.6	2.62	27	-0.1	0.83	18	9.9%	2.66 [1.83, 3.49]
Farinha et al. (2021) [16] - CTG	0.2	0.86	25	0.2	0.54	10	10.5%	0.00 [-0.73, 0.73]
Farinha et al. (2021) [16] - ITG	0	1.71	28	0.2	0.54	10	10.6%	-0.13 [-0.85, 0.59]
Häfele et al. (2022) [21]	0	0.76	11	0	0.16	10	9.8%	0.00 [-0.86, 0.86]
Martínez et al. (2015) [34]	1.19	6.41	16	-1.16	2.56	10	10.1%	0.43 [-0.37, 1.23]
Pernambuco et al. (2013) [41]	3.7	4.93	36	-0.7	1.13	31	11.7%	1.18 [0.65, 1.70]
Silva et al. (2018) [54]	0.68	0.6	13	0.57	0.43	9	9.8%	0.20 [-0.66, 1.05]
Total (95% CI)			**201**			**120**	**100.0%**	**0.63 [0.11, 1.16]**

Heterogeneity: $Tau^2 = 0.55$; $Chi^2 = 39.98$, df = 9 (P < 0.00001); $I^2 = 77\%$
Test for overall effect: Z = 2.36 (P = 0.02)

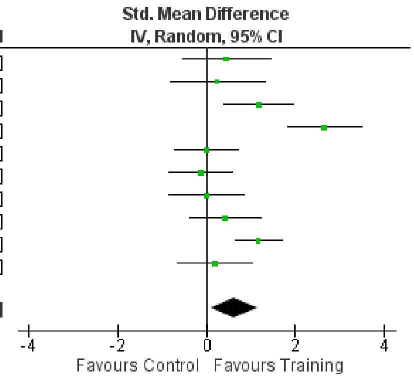

Figure 3. Random effects meta-analysis comparing aquatic aerobic training programs and control groups on agility and dynamic balance. SD = standard deviation; CTG = continuous training group; ITG = interval training group.

Study or Subgroup	Training Mean	Training SD	Training Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Bocalini et al. (2008) [8]	12	1.45	25	1	1.35	10	22.3%	11.00 [9.99, 12.01]
Bocalini et al. (2010) [9]	6	2.04	27	0.1	2.75	18	22.1%	5.90 [4.41, 7.39]
Farinha et al. (2021) [16] - CTG	1.7	3.85	25	0	6.18	10	19.1%	1.70 [-2.42, 5.82]
Farinha et al. (2021) [16] - ITG	1.2	4.4	28	0	6.18	10	19.1%	1.20 [-2.96, 5.36]
Häfele et al. (2022) [21]	-1.1	3.51	11	4.2	7.89	10	17.4%	-5.30 [-10.61, 0.01]
Total (95% CI)			**116**			**58**	**100.0%**	**3.39 [-1.22, 8.00]**

Heterogeneity: $Tau^2 = 24.49$; $Chi^2 = 83.45$, $df = 4$ ($P < 0.00001$); $I^2 = 95\%$
Test for overall effect: $Z = 1.44$ ($P = 0.15$)

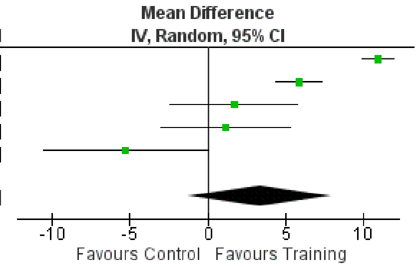

Figure 4. Random effects meta-analysis comparing aquatic aerobic training programs and control groups on flexibility of lower limbs. SD = standard deviation; CTG = continuous training group; ITG = interval training group.

ARTIGO 2

Artigo intitulado "**Cardiorespiratory parameters comparison between incremental protocols performed in aquatic and land environments by healthy individuals: a systematic review and meta-analysis**" publicado no periódico *Sports Medicine*.

Artigo aceito em 4 de Abril de 2022.
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CARDIORESPIRATORY PARAMETERS COMPARISON BETWEEN INCREMENTAL PROTOCOLS PERFORMED IN AQUATIC AND LAND ENVIRONMENTS BY HEALTHY INDIVIDUALS: A SYSTEMATIC REVIEW AND META-ANALYSIS

Short title: Comparison of aquatic and land-based incremental protocols

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Abstract

Background Physical properties of water cause physiological changes in the immersed human body compared with the land environment. Understanding the magnitude of cardiorespiratory alterations might ensure adequate intensity control during aquatic exercise programs.

Objective We aimed to compare the oxygen uptake (VO_2), heart rate (HR), and rating of perceived exertion (RPE) parameters during aquatic and land incremental tests.

Methods Four databases (PubMed, LILACS, EMBASE, and SPORTDiscus) were searched in September 2020. Eligibility criteria included studies in a crossover design comparing aquatic and land incremental tests for healthy individuals with at least one of the following parameters: VO_2 (maximal, VO_{2max}; anaerobic threshold, VO_{2AT}), HR (HR_{max}; HR_{AT}), and RPE (RPE_{max}; RPE_{AT}). The random-effects meta-analysis included mean difference and 95% confidence interval for VO_2 and HR or standardized mean difference for RPE. The Joanna Briggs Institute Critical Appraisal tool was adapted to assess methodological quality.

Results Twenty-eight studies were eligible and included in the meta-analysis. Aquatic protocols showed lower values compared with land for VO_{2max} (− 7.07 mL.kg^{-1}.min^{-1}; − 8.43 to − 5.70; n = 502), VO_{2AT} (− 6.19 mL.kg^{-1}.min^{-1}; − 7.66 to − 4.73; n = 145), HR_{max} (− 11.71 bpm; − 13.84 to − 9.58; n = 503), and HR_{AT} (− 15.29 bpm; − 19.05 to − 11.53; n = 145). RPE_{max} (0.01; − 0.16 to 0.18; n = 299) and RPE_{AT} (− 0.67; − 1.35 to 0.02; n = 55) values were similar between aquatic and land protocols.

Conclusions Our study reinforces the specificity of the environment during incremental tests for prescribing exercises based on physiological parameters as VO_2 and HR parameters presented lower values in aquatic protocols than land protocols. Conversely, RPE seems an interchangeable measure of exercise intensity, with similar values during the protocols in both environments. Substantial levels of heterogeneity

were present for the VO_{2max} and HR_{max} meta-analyses, and as such, results should be interpreted with attention.

Protocol Registration This study was registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD42020212508).

Key points:

1. Cardiorespiratory parameters (i.e., maximal oxygen uptake, anaerobic thresholds of oxygen uptake, maximal heart rate, and anaerobic thresholds of heart rate) presented lower values during incremental protocols performed in the aquatic environment compared with the land environment, while no difference was found between protocols for the maximal rating of perceived exertion or rating of perceived exertion anaerobic threshold.
2. Subgroup analyses based on the use of the ergometers indicated differences in cardiorespiratory parameters between environments only for studies that employed aquatic protocols without ergometers, while no difference was observed for studies with aquatic ergometers.
3. Future studies that intend to compare protocols in water and land should pay attention to the adequate reporting of methods.

1. INTRODUCTION

Structuring an aerobic exercise program involves manipulating several variables; one of them is the intensity, which deserves a fundamental consideration when tailoring an aerobic exercise prescription and whose control is directly related to the effectiveness of the exercise program [1]. Aerobic exercises are prescribed according to relative intensity, designed to produce stress loads more equivalent in individuals with different absolute physical capacities and allow predictable adaptive responses [2].

Among several parameters for monitoring the intensity, the main parameters are the cardiorespiratory (i.e., percentage of maximal oxygen uptake, $\%VO_{2max}$ and percentage of maximal heart rate, $\%HR_{max}$), owing to their linear relationship with the intensity during incremental exercise tests [3–5]. Cardiorespiratory parameters associated with the anaerobic threshold can be used as a more precise and individualized method to prescribe the intensity of aerobic exercises. The anaerobic threshold is the transition point between the predominance of the aerobic to the anaerobic system [2,6]. In addition, the rating of perceived exertion (RPE) is a practical possibility for intensity control, which is directly related to $\%VO_{2max}$ and $\%HR_{max}$ [7–10] and anaerobic thresholds in several modes of exercise [11–13]. However, for these mentioned parameters, the reference values might be influenced by factors such as the environment, mode of exercise, and the ergometer used. Accordingly, the reference value for tailoring a target training zone must be reached in a maximal test protocol that considers the exercise’s specificity in real practice to avoid underestimated or overestimated percentage values.

The aquatic environment offers an alternative possibility for physical training. Among the modes of aquatic exercise, those performed in shallow or deep water (e.g., water-based stationary exercises, shallow water running/walking, deep water running) or in aquatic ergometers (e.g., treadmill or cycle ergometer), both in the vertical position, can be highlighted. However, it should note that water immersion exposes the human body to conditions different from those on land, causing physiological changes because of the action of specific physical properties of water [14, 15]. In summary, during thermoneutral immersion in a vertical position, central volume expansion occurs, increase in the cardiac output, and activation of cardiovascular mechanoreceptors, causing a tonic inhibition in the flow of sympathetic nervous activity, which controls the systemic circulation and renal function. Consequently, several hormonal changes occur, such as reducing anti-diuretic hormones, greater atrial natriuretic peptide secretion, and the suppression of hormonal axes with critical clinical repercussions, promoting diuresis and natriuresis, aiming at the return of the basal plasma volume [14].

Therefore, during and post-aquatic training programs, the prescription and monitoring of intensity and the cardiorespiratory adaptation assessment must consider these physiological alterations. The VO_2 and HR at maximal effort and anaerobic threshold are intensity indicators widely used in the aquatic environment [16–20] and affected by water immersion. Thus, it is a mistake to base the desired training percentage on those obtained for land aerobic exercise protocols. Nevertheless, RPE is also widely used in the aquatic environment [21, 22], but possible differences with the land environment still need to be elucidated.

To demonstrate the magnitude of differences from land to water, since the 1990s, studies with deep water running have compared the behavior of cardiorespiratory and RPE parameters at the maximal and anaerobic threshold between the two environments [23, 24]. More recently, aquatic-based ergometers [25, 26] and shallow water exercises [27–29] have also been investigated to understand the effects of immersion during incremental tests in different modes of exercise. Additionally, a recent systematic review described specific testing properties for cardiorespiratory fitness protocols used in the aquatic environment [30]. However, its purpose was not to compare these responses with the land environment.

Despite a considerable amount of original research comparing VO_2, HR, and RPE parameters between incremental tests performed in the aquatic and land environments, there has been no systematic review and synthesis of the current literature on this topic to the best of the authors' knowledge. Summarizing these differences can give better guidance on the magnitude of responses in each environment. In addition, it is necessary to verify if the effect of different modes of exercise and the use of aquatic-based ergometers may influence the magnitude of difference between environments in such parameters (i.e., VO_2, HR, and RPE). These findings will help understand the need for specific incremental tests in the aquatic environment for assessing the adaptations from an aquatic training program and the suitable intensity prescription and monitoring during the exercise practice. Therefore, this review aimed to compare VO_2, HR, and RPE parameters (maximal and associated at the anaerobic threshold) during incremental tests between the aquatic and land environments, reviewing crossover studies that have compared these two conditions performed by healthy individuals. Our initial hypotheses were that VO_2 and HR parameters would present lower values in aquatic protocols than land protocols, while the RPE values would be similar between environments.

2. METHODS

A systematic review with a meta-analysis was conducted and reported according to the Cochrane Handbook for Systematic Reviews of Interventions and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [31–33].

2.1 Eligibility Criteria

Eligibility criteria are shown in Table 1. This review included crossover studies that investigated the cardiorespiratory responses during incremental test protocols up to the maximum effort in different modes of aquatic exercise performed in the vertical position (i.e., stationary waterbased exercises, shallow water running/walking, deep water running, aquatic treadmill, or aquatic cycle ergometer) compared to a land environment incremental test condition. Studies with healthy men and women over 18 years of age were included. There was no restriction for the upper age limit or the level of physical fitness. Exclusion criteria included studies with participants affected by cardiovascular or metabolic diseases (e.g., diabetes mellitus, coronary heart disease, dyslipidemia), hypertension risk factor, or osteoarticular disorders. Studies were limited to Portuguese, English, and Spanish languages published in peer-reviewed journals.

Table 1 Eligibility criteria

Criterion	**Description**
Publication language	English, Portuguese and Spanish
Design of study	Transversal Crossover
Participants	Health adults (aged ≥ 18 years), men and women
Exposure	Incremental test up to the maximum effort in any mode of aquatic exercise performed in the vertical position (i.e., stationary water-based exercises, shallow water running/walking, deep water running, aquatic treadmill, or aquatic cycle ergometer)
Comparator	Incremental test up to the maximum effort in the land environment
Parameters	Oxygen uptake (VO_{2max} and VO_{2AT}), heart rate (HR_{max} and HR_{AT}), and rating of perceived exertion (RPE_{max} and RPE_{AT})

HR_{AT} heart rate anaerobic threshold, HR_{max} maximal heart rate, RPE_{AT} rating of perceived exertion anaerobic threshold, RPE_{max} maximal rating of perceived exertion, VO_{2AT} oxygen uptake anaerobic threshold, VO_{2max} maximal oxygen uptake.

2.2 Information Sources

Searches were carried out in four electronic databases for indexed full-text publications (i.e., PubMed, LILACS, EMBASE, and SPORTDiscus) between the 7th and 8th of September, 2020. The search included studies from 1946 (database inception) until September 2020. In addition, the reference lists from retrieved articles were manually checked. Literature search strategies were developed using medical subject headings (MeSH) and text words. The full search strategies per database are presented in the Electronic Supplementary Material.

2.3 Selection Process

All retrieved reports were imported for Endnote X8 reference management software, and duplicates were removed. According to the eligibility criteria, two reviewers (LSA and MSH) independently assessed titles and abstracts of potential previously searched studies. Before the eligibility process, a pilot screening of 100 articles was carried out for standardization. Any disagreements between the pair were solved by discussion. All abstracts that did not provide sufficient information regarding the inclusion and exclusion criteria were assessed in the full text.

2.4 Data Collection Process

All studies that met the eligibility criteria at the full-text level were included in the data extraction process. One author (LSA) extracted the data and then another author (MSH or GBD) confirmed the data. Disagreements were resolved by personal discussion between the reviewers to agree or consult with a fourth independent reviewer (CLA). A coded data sheet was used to extract the maximal and anaerobic threshold data of VO_2, HR, and RPE (i.e., VO_{2max}, VO_{2AT}, HR_{max}, HR_{AT}, RPE_{max}, and RPE_{AT}) during aquatic and land incremental tests. In addition, the following information was collected: author, year of publication, journal, participants' characteristics (i.e., sample size, age, sex, and anthropometric characteristics), and test protocols in water and land (i.e., exercises, initial intensity, increments, time of each stage, termination criteria, water depth, room temperature or water temperature). The authors of the included studies were contacted when any data were not found in the full text.

2.5 Study Risk of Bias Assessment

The Joanna Briggs Institute Critical Appraisal Tool for Analytical Cross-Sectional Studies [34] was adapted to assess included studies' methodological quality. The tool consists of eight questions with the following possible answers: yes, no, unclear, or not/applicable. Studies were rated based on criteria provided by the Joanna Briggs Institute guideline [34]. Questions 5 (i.e., Were confounding factors identified?) and 6 (i.e., Were strategies to deal with confounding factors stated?) were not included in our analysis because do not apply to the crossover design. As the same participants performed the protocols, we assume that there were no inter-subject confounders. Additionally, we included two more items: (1) "Was the randomization method described in detail?" If the authors only describe that there was randomization to the order of the protocols, but do not explain how it was done, we rated as unclear. (2) "Was the interval time between protocols described?" Declaring the interval between protocols helps to identify a possible carry-over effect.

The assessment was made by pairs of reviewers independently (LSA and MSH, GBD and CLA, CEB and SSP) and based on the information reported in the published paper. A pre-pilot test was made to consolidate and clarify the reviewers' team rating criteria. Discrepancies were resolved by personal discussion between pairs or by consultation with all authors. We do not generate a total score for studies. The presentation and discussion of studies rating are based on the tool's items.

2.6 Synthesis Methods

A separate random-effects meta-analysis for each review variable was performed using the Review Manager software (version 5.4) when two or more studies reported the same variable. All studies had the same participants in one or more exercise protocols in the aquatic protocol and a control exercise protocol on land. The raw data (i.e., means, standard deviation, and sample size) were extracted from these protocols. Studies were individually weighted using the inverse variance method.

Raw mean difference (MD) with 95% confidence intervals (95% CIs) was used for meta-analyses when the included studies reported results for review variables using the same measurement scale (i.e., VO_{2max}, VO_{2AT}, HR_{max}, HR_{AT}, and RPE_{AT}). For the VO_{2max}, we transformed the unit of measure in two studies [35, 36], from $mL\cdot min^{-1}$ and $L\cdot min^{-1}$ to $mL\cdot kg^{-1}\cdot min^{-1}$, based on mean participants' body mass. Standardized MD (SMD) with 95% CI was calculated for RPE_{max} because studies used different measurement scales. Although the intra-subject correlation is recommended for adjustment in a systematic review with meta-analysis using studies with a crossover design, we did not include this analysis because of the unavailable individual data in each study included.

For studies that presented data stratified by sex [23, 37], level of physical fitness (i.e., trained and untrained) [38, 39], adapted or not with the exercise protocol [40], or age group (i.e., young and middle-aged/elderly) [41, 42], the subgroups were treated as individual studies. This choice was adopted because the groups are independent of each other, and each provides unique information. In studies with more than one protocol in the water in the same participants, but varying the movement performed [27, 28], mode of exercise (i.e., deep and shallow water) [43], water temperature [26], water stationary bikes [44], or wearing/not wearing shoes [25], the data were combined in a single group by weighted mean.

A Chi-square test evaluated the statistical significance of heterogeneity. The I^2 statistic estimated the amount of study heterogeneity based on the p value being < 0.10 or the I^2 value > 40%, indicating significant heterogeneity. As the ergometer use can be a source of heterogeneity between studies, subgroup analyses were performed considering studies with ergometer and without ergometer use. Other factors contributing to heterogeneity, such as fitness level, sex, and age, were not considered for subgroup or sensitivity analysis because of the low number of studies for each factor category.

3. RESULTS

3.1 Study Selection

The search retrieved 1841 records. After removing 370 duplicates, 1424 titles and abstracts were read, of which 1378 were not eligible. Out of 46 articles read, 22 were excluded for one of the following reasons: (1) type of study; (2) participants; and (3) protocol. Five additional studies identified by hand searching in the references of the included studies were eligible [24, 25, 44–46]. Of 29 eligible studies included, two presented the same data [37, 47], and one was removed from the analysis. We chose to include the study that contemplated the most significant number of variables of interest in this review [37]. A flow diagram of the review process is in Fig. 1.

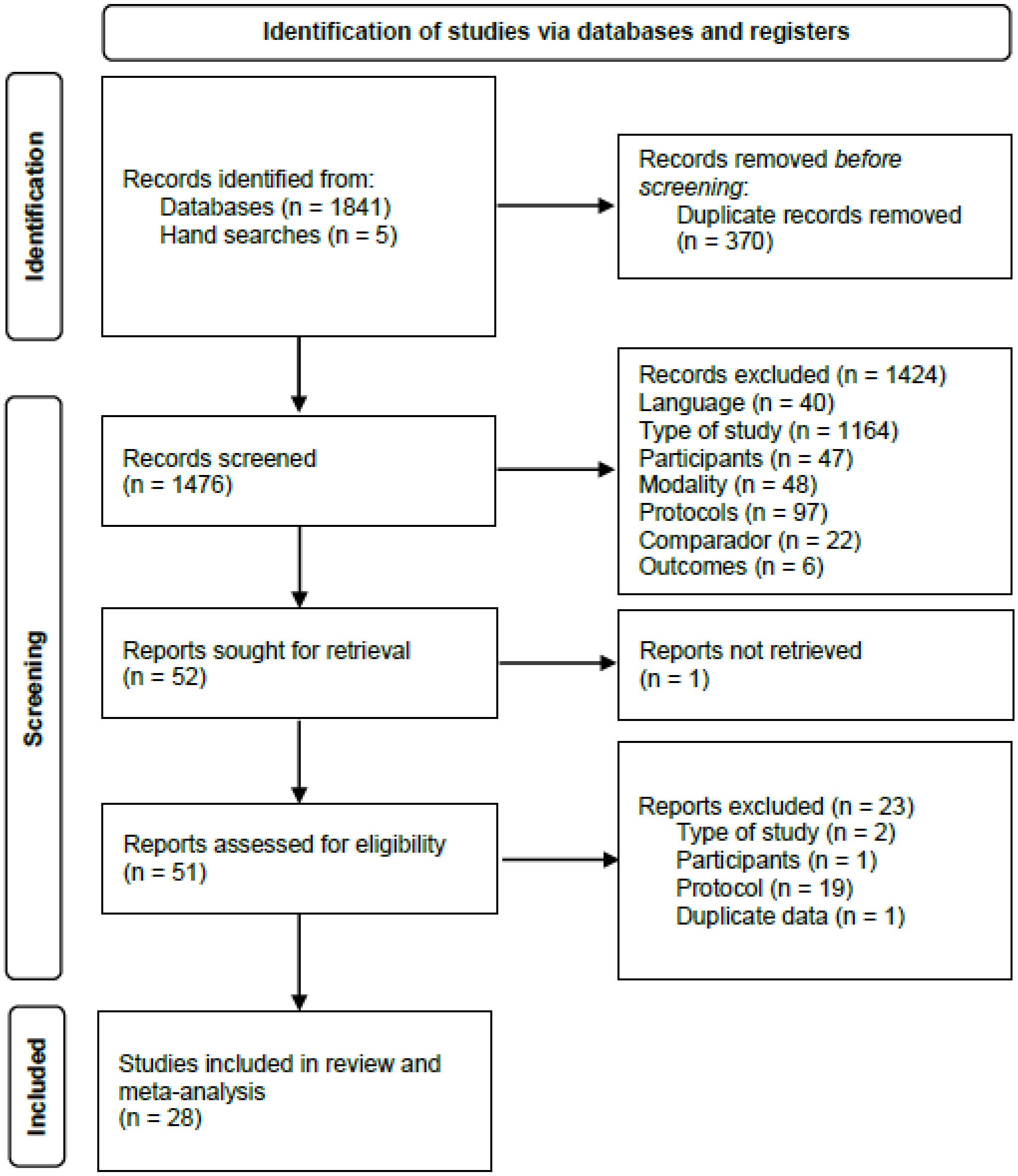

Fig. 1 Literature search flow chart

3.2 Study Characteristics

A summary of the sample characteristics and test protocols on aquatic and land environments for included studies is shown in Table 2. Included studies were from USA [23, 25, 29, 36, 37, 48–50], Canada [24, 35, 39, 41, 46], Brazil [27, 28, 45, 51, 52], Japan [42, 53, 54], UK [40, 43], Italy [38, 44], New Zealand [55], Spain [56], and Portugal [26]. The total number of participants was 512 (275 were male, 237 were female). Out of 28 included studies, eight included male-only participants [25, 26, 36, 38, 42, 43, 53, 56], eight included female-only participants [27–29, 41, 45, 51, 52, 55], and 12 included both [23, 24, 35, 37, 39, 40, 44, 46, 48–50, 54]. The sample of studies consisted of young people for most of the studies [23–29, 36–42, 44–46, 49–54, 56] and middle-aged or elderly adults [35, 41–43, 48, 55].

Relative to aquatic protocols, 16 studies had the deep water running exercises [23, 24, 35–37, 39–42, 45, 49, 51, 53–56], five had shallow water exercises [27–29, 38, 52], and one study involved both modes of aquatic exercise (i.e., deep and shallow water) [43]. Additionally, in six studies the aquatic protocol was performed in ergometers, three studies in treadmills [25, 48, 50], and three studies in cycle ergometers [26, 44, 46]. The comparator protocols (i.e., land protocols), were performed on treadmills for most of the studies [23–25, 27–29, 35–43, 45, 48–56] and cycle ergometers in the remaining three studies [26, 44, 46].

From 28 studies, 27 assessed VO_{2max} [23–29, 35–46, 48–55] and HR_{max} [23–26, 28, 29, 35–46, 48–56] and 15 reported RPE_{max} data [24, 25, 27–29, 36, 37, 39, 40, 42, 48, 50, 53–55]. Seven studies presented independent groups and were treated as individual studies, totalizing 34 combinations for VO_{2max} and HR_{max}, and 19 combinations for RPE_{max}. For VO_{2AT}, seven studies reported data, with eight combinations [24, 27, 28, 39, 40, 51, 52], six studies with seven combinations reported data of HR_{AT} [24, 28, 39, 40, 51, 52] and four studies with five combinations reported data of RPE_{AT} [24, 27, 39, 40].

Table 2 Characteristics of the sample and test protocols on land and aquatic environments of the included studies.

Author (year)	Participants	Incremental tests	
		Non-ergometers protocols	
		Land	Water
Alberton et al. [27]	Nine young women **Age:** 22.89 ± 1.81 years **Height:** 166 ± 7 cm **Weight:** 58.46 ± 4.19 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed **Initial intensity:** 5 $km.h^{-1}$ with a 1% inclination for 3 min **Increments:** 1 $km.h^{-1}$ every 2 min maintaining the inclination **Termination Criteria:** Exhaustion **Room Temperature:** 24 ºC	**Exercise:** SR, FK and JJ **Intensity control:** Cadence defined by a metronome **Initial intensity:** 85 $beats.min^{-1}$ for 3 min **Increments:** 15 $beats.min^{-1}$ every 2 min **Termination Criteria:** Exhaustion or unable to maintain the cadence **Water Temperature:** 31-32 ºC **Water depth:** Between xiphoid process and shoulders
Alberton et al. [28]	Twenty young women **Age:** 24.0 ± 2.5 years **Height:** 163.3 ± 6.7 cm **Weight:** 60.0 ± 6.7 kg **BMI:** NR **Body fat percentage:** 29.3 ± 5.0%	**Exercise:** TRE **Intensity control:** Speed **Initial intensity:** 5 $km.h^{-1}$ and 1% inclination for 2 min **Increments:** 1 $km.h^{-1}$ every 1 min maintaining the inclination **Termination Criteria:** Exhaustion or unable to maintain the speed **Room Temperature:** 22-26 ºC.	**Exercise:** SR, FK and CCS **Intensity control:** Cadence defined by a metronome **Initial intensity:** 80 $beats.min^{-1}$ for 2 min **Increments:** 10 $beats.min^{-1}$ every 1 min **Termination Criteria:** Exhaustion or unable to maintain the cadence **Water Temperature:** 32 ºC **Water depth:** Xiphoid process
Azevedo et al. [40]	Seventeen runners, either adapted or not adapted to deep water running Non-adapted (n = 7; women = 6) **Age:** 30.9 ± 5.3 years **Height:** 165 ± 6 cm **Weight:** 59.8 ± 6.1 kg **BMI:** NR **Body fat percentage:** NR Adapted (n = 10; women = 5) **Age:** 32.3 ± 6.5 years **Height:** 172 ± 12 cm **Weight:** 68.9 ± 17.1 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** 6 $km.h^{-1}$ **Increments:** 1 $km.h^{-1}$ every 1 min up to a speed of 14 $km.h^{-1}$, when the treadmill was inclined by 5% every 1 min **Termination Criteria:** Exhaustion **Room Temperature:** NR	**Exercise:** DWR **Intensity control:** Cadence defined by a metronome **Initial intensity:** 104 $steps.min^{-1}$ for 1 min **Increments:** 8 $steps.min^{-1}$ every 1 min **Termination Criteria:** Exhaustion or unable to maintain the cadence **Water Temperature:** 28-30 ºC
Brown et al. [37]	Twenty-four young adults Men (n = 12) **Age:** 21.0 ± 1.9 years **Height:** 179.7 ± 4.8 cm **Weight:** 77.2 ± 13.0 kg	**Exercise:** TRE **Intensity control:** Speed corresponding to step frequency of test in water and inclination **Initial intensity:** 2.52 $km.h^{-1}$ **Increments:** 0.54-1.02 $km.h^{-1}$ every 3 min up to a	**Exercise:** DWR **Intensity control:** Cadence defined by a metronome **Initial intensity:** 72 $strides.min^{-1}$ for 3 min **Increments:** 12 $strides.min^{-1}$ every 3 min

	BMI: NR **Body fat percentage:** 14.1 ± 5.8% Women (n = 12) **Age:** 20.0 ± 0.8 years **Height:** 168.5 ± 4.7 cm **Weight:** 60.4 ± 7.3 kg **BMI:** NR **Body fat percentage:** 23.2 ± 4.7%	speed of 7.56, when the treadmill was inclined by 5% every 2 min. **Termination Criteria:** Unable to maintain the cadence **Room Temperature:** 21.7 ± 0.7 ºC	**Termination Criteria:** Unable to maintain the cadence or DWR technique **Room Temperature:** 29.6 ± 0.5 ºC
Butts et al. [23]	Twenty-four young adults Women (n = 12) **Age:** 21.9 ± 2.4 years **Height:** 164.6 ± 4.2 cm **Weight:** 59.6 ± 6.4 kg **BMI:** NR **Body fat percentage:** NR Men (n = 12) **Age:** 20.6 ± 1.9 years **Height:** 178.2 ± 6.6 cm **Weight:** 70.5 ± 7.3 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Inclination **Initial intensity:** 8 km.h^{-1} for women and 9.7 km.h^{-1} for men with 0% inclination during 5 min. Thereafter, 9.7 km.h^{-1} for women and 11.3 km.h^{-1} for men with a 2.5% inclination for 2 min. **Increments:** 2.5% every 2 min **Termination Criteria:** Exhaustion **Room Temperature:** NR	**Exercise:** DWR **Intensity control:** Cadence defined by a metronome **Initial intensity:** 100 beats.min^{-1} **Increments:** 20 beats.min^{-1} every 2 min **Termination Criteria:** When the subjects fell behind the cadence, or when their physiologic responses did not increase in response to a higher cadence, they were strongly encouraged to “go all out” and complete at least 1 more entire minute. **Water Temperature:** 29 ± 0.5 ºC
Chu et al. [41]	Eighteen women Young women (n = 9) **Age:** 23.6 ± 4.7 years **Height:** 165.5 ± 3.6 cm **Weight:** 58.4 ± 8.6 kg **BMI:** NR **Body fat percentage:** NR Older women (n = 9) **Age:** 63.3 ± 2.9 years **Height:** 162.1 ± 9.1 cm **Weight:** 63.4 ± 9.4 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Inclination **Initial intensity:** 8.9 km.h^{-1} for young and 5.6 km.h^{-1} for older with 0% inclination **Increments:** 2% every 1 min **Termination Criteria:** Exhaustion **Room Temperature:** 21 ºC	**Exercise:** DWR **Intensity control:** Load increase **Initial intensity:** 500g for young and 200-300g for older group **Increments:** 200g for young group and 100-200g for older group every 1 min **Termination Criteria:** Exhaustion **Water Temperature:** 28 ºC
Conti et al. [38]	Twelve young men Untrained (n = 6) **Age:** 22 ± 1 years **Height:** 170 ± 7 m **Weight:** 58.0 ± 12.4 kg **BMI:** NR **Body fat percentage:** NR Trained (n = 6) **Age:** 19 ± 1 years	**Exercise:** TRE **Intensity control:** Speed **Initial intensity:** 7 km.h^{-1} during 3 min, followed by 10 km.h^{-1} for 2 min with 1% inclination **Increments:** 1 km.h^{-1} every 1 min maintaining the inclination **Termination Criteria:** Exhaustion **Room Temperature:** 24-26 ºC	**Exercise:** SR **Intensity control:** Cadence defined by a metronome **Initial intensity:** self-selected stride frequency for 3 min **Increments:** 12 strides.min^{-1} every 1 min **Termination Criteria:** Exhaustion **Water Temperature:** 29-30 ºC **Water depth:** Lower than xiphoid process

	Height: 177 ± 5 m **Weight:** 66 ± 5.1 kg **BMI:** NR **Body fat percentage:** NR		
Cuesta-Vargas et al. [56]	Ten male volleyball players **Age:** Unclear **Height:** Unclear **Weight:** Unclear **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed **Initial intensity:** 5 km.h^{-1} during 5 min with 1% inclination **Increments:** 1 km.h^{-1} every 2 min **Termination Criteria:** Physiological or volitional fatigue **Room Temperature:** Unclear	**Exercise:** DWR **Intensity control:** Cadency defined by a metronome **Initial intensity:** 60 cycles.min^{-1} for 5 min (1 cycle = 2 steps) **Increments:** 10 cycle.min^{-1} every 2 min **Termination Criteria:** Physiological or volitional fatigue. Each participant was instructed to "go all out" during the final minute. **Water Temperature:** 28 ºC
Dowzer et al. [43]	Fifteen male runners **Age:** 40.93 ± 9.48 years **Height:** 172 ± 7 cm **Weight:** 69 ± 9.03 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Inclination **Initial intensity:** Individualized predetermined speed (mean = 13.7 km.h^{-1}) during 4 min **Increments:** 2.5% inclination every 3 min **Termination Criteria:** Exhaustion **Room Temperature:** NR	**Exercise:** DWR and SWR **Intensity control:** Cadence defined by a metronome **Initial intensity:** 120 strides.min^{-1} for DWR and 132 strides.min^{-1} for SWR going up in increments of 12 strides.min^{-1} for the initial workload **Increments:** 8 strides.min^{-1} every stage (stage duration unclear) **Termination Criteria:** Exhaustion **Water Temperature:** 29 ºC **Water depth:** Waist for SWR
Frangolias and Rhodes [24]	Thirteen elite distance runners trained in DWR <u>Women (n = 5)</u> **Age:** 24.2 ± 6.7 years **Height:** 165.6 ± 4.3 cm **Weight:** 54.2 ± 4.9 kg **BMI:** NR **Body fat percentage:** NR <u>Men (n = 8)</u> **Age:** 27.3 ± 4.1 years **Height:** 182.5 ± 5.0 cm **Weight:** 71.5 ± 4.6 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** 8.0 km.h^{-1} **Increments:** 0.8 km.h^{-1} every 1 min up to a speed of 19.2 km.h^{-1} (at minute 15), when the treadmill was inclined by 2% every 1 min **Termination Criteria:** Physiological or volitional fatigue **Room Temperature:** NR	**Exercise:** DWR **Intensity control:** Load increase **Initial intensity:** 500 g for women and 750 g for men group **Increments:** 400 g every 1 min up to minute 15, when the load was increased by 500 g for women and 750 g for men group **Termination Criteria:** Exhaustion **Water Temperature:** 28 ºC
Frangolias et al. [39]	Twenty-two endurance runners (women = 8) <u>Untrained (n = 6)</u> **Age:** 26.3 ± 4.7 years **Height:** 176.6 ± 9.3 cm **Weight:** 63.4 ± 8.7 kg	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** 8.0 km.h^{-1} **Increments:** 0.8 km.h^{-1} every 1 min up to a speed of 19.2 km.h^{-1} (at minute 15), when the treadmill was inclined by 2% every 1 min	**Exercise:** DWR **Intensity control:** Load increase **Initial intensity:** 500 g for women and 750 g for men group **Increments:** 400 g every 1 min up to minute 15, when the load was increased by 500 g for women

	BMI: NR **Body fat percentage:** NR Trained (n = 16) **Age:** 26.7 ± 4.7 years **Height:** 176.2 ± 9.0 cm **Weight:** 64.9 ± 9.4 kg **BMI:** NR **Body fat percentage:** NR	**Termination Criteria:** Exhaustion **Room Temperature**: NR	and 750 g for men group **Termination Criteria:** Exhaustion **Water Temperature:** 28 ºC
Gayda et al. [35]	Twenty-one adults older than 45 years (women = 10) **Age:** 60 ± 7 years **Height:** 167 ± 7 cm **Weight:** 82 ± 20 kg **BMI:** 29.2 ± 6.0 kg.m^{-2} **Fat percentage:** 32 ± 7%	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** Individualized predetermined speed (mean = 2.89 ± 0.35 km.h^{-1} and 2.42 ± 0.96%) **Increments:** Individualized (mean = 0.6 ± 0.18 km.h^{-1} and 1.96 ± 0.5%) every 2 min **Termination Criteria:** Exhaustion **Room Temperature:** NR	**Exercise:** DWR **Intensity control:** Cadence defined by a metronome **Initial intensity:** 56 cycles.min^{-1} for 2 min **Increments:** Individualized in order to reach the maximum in less than 8 min (8-30 cycles.min^{-1}) every 2 min **Termination Criteria:** Exhaustion or unable to maintain the cadence **Water Temperature:** 30 ºC
Kanitz et al. [51]	Twelve young women **Age:** 23.2 ± 1.9 years **Height:** 161.4 ± 5.6 cm **Weight:** 57.9 ± 7.1 kg **BMI:** 20.9 ± 5.1 kg.m^{-2} **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed **Initial intensity:** 6 km.h^{-1} with a 1% inclination for 3 min **Increments:** 1 km.h^{-1} every 2 min maintaining the inclination **Termination Criteria:** Until maximum effort **Room Temperature:** 22-24 ºC	**Exercise:** DWR **Intensity control:** Cadence defined by a metronome **Initial intensity:** 85 beats.min^{-1} for 3 min **Increments:** 15 beats.min^{-1} every 2 min **Termination Criteria:** Until maximum effort **Water Temperature:** 30 ºC
Kruel et al. [52]	Nine young women **Age:** 23.0 ± 1.9 years **Height:** 166 ± 6 cm **Weight:** 58.6 ± 4.4 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed **Initial intensity:** 6 km.h^{-1} with 1% inclination for 3 min **Increments:** 1 km.h^{-1} every 2 minutes maintaining the inclination **Termination Criteria:** Exhaustion **Room Temperature:** 21-26º	**Exercise:** SR **Intensity control:** Cadence defined by a compact disc **Initial intensity:** 85 beats.min^{-1} for 2 min **Increments:** 15 beats.min^{-1} every 2 min **Termination Criteria:** Exhaustion **Water Temperature:** 31–32 ºC **Water depth:** Xiphoid process
Masumoto et al. [54]	Eleven recreational runners (women = 1) **Age:** 22.6 ± 2.6 years **Height:** 174.1 ± 6.1 cm **Weight:** 74.4 ± 9.4 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** 6 km.h^{-1} for 5 min **Increments:** 1 km.h^{-1} every minute up to a speed of 14 km.h^{-1}, when the treadmill was inclined by 5% every 1 min **Termination Criteria:** Exhaustion **Room Temperature:** 26 ºC	**Exercise:** DWR **Intensity control:** Cadence defined by a metronome **Initial intensity:** 52 strides.min^{-1} (1 stride = 2 steps) **Increments:** 4 strides.min^{-1} every 1 min **Termination Criteria:** Exhaustion or unable to maintain the cadence **Water Temperature:** 28 ºC

Mercer and Jensen [49]	Twenty-eight young adults Men (n = 15) **Age:** 24.3 ± 4.7 years **Height:** 180 ± 8 cm **Weight:** 79.5 ± 10.8 kg **BMI:** NR **Body fat percentage:** NR Women (n = 13) **Age:** 21.0 ± 1.3 years **Height:** 170 ± 6 cm **Weight:** 58.9 ± 7.0 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** 4.8 $km.h^{-1}$ with 3% inclination **Increments:** In the second stage, the elevation was increased to 7.5% and remained constant for all subsequent stages. After, 0.8 $km.h^{-1}$was increased every 1 min. **Termination Criteria:** NR **Room Temperature:** 22.0 ± 4.3 ºC	**Exercise:** DWR **Intensity control:** Load increase **Initial intensity:** 0.57 kg **Increments:** 0.57 kg every 1 min **Termination Criteria:** Unable to maintain the bucket suspended **Water Temperature:** 26.9 ± 1.6 ºC
Michaud et al. [36]	Six male runners **Age:** 25.5 ± 5.1 years **Height:** 169.0 ± 3.0 cm **Weight:** 68.1 ± 9.2 kg **BMI:** NR **Body fat percentage:** 7.6 ± 2.4%	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** Individualized predetermined speed **Increments:** 1.6 $km.h^{-1}$ every 3 min up to 16.1 $km.h^{-1}$. After, the inclination was increased 2% every 3 min. **Termination Criteria:** Fatigue **Room Temperature:** 19-23ºC	**Exercise:** DWR **Intensity control:** Load increase **Initial intensity:** Individualized **Increments:** Individualized predetermined workloads every 3 min **Termination Criteria:** Unable to maintain proper running form and remain within the target area **Water Temperature:** 29-30 ºC
Nagle et al. [29]	Twenty-three young women **Age:** 20.1 ± 2.9 years **Height:** 163 ± 5.2 cm **Weight:** 63.0 ± 9.5 kg **BMI:** 23.5 ± 3.4 $kg.m^{-2}$ **Body fat:** 26.3 ± 7.6%	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** 2.74 $km.h^{-1}$ and 10% inclination **Increments:** 0.9-1.45 $km.h^{-1}$ and 2% inclination every 3 min (Bruce Protocol) **Termination Criteria:** Exhaustion **Room Temperature:** NR	**Exercise:** SWR **Intensity control:** Determined subjectively **Initial intensity:** 4 x 22 m at moderate intensity and 10 s rest **Increments:** 3 x 22 m at hard intensity and 5 s rest, 2 x 22 m at very hard intensity and 3-5 s rest, 4-6 x 22 m at maximal intensity. Rest period = Rest time between pool lengths. **Termination Criteria:** Exhaustion or unable to maintain the velocity per pool length **Water Temperature:** 27.5 ºC **Water depth:** Between xiphoid process and mid axillary region
Nakanishi et al. [42]	Twenty-eight men Young men (n = 14) **Age:** 20.4 ± 3.3 years **Height:** 170.7 ± 6.2 cm **Weight:** 65.1 ± 11.4 kg **BMI:** NR **Body fat percentage:** 18.6 ± 5.7 % Middle aged men (n = 14) **Age:** 38.6 ± 4.4 years	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** 9.6 $km.h^{-1}$ and 0% inclination for 4 min **Increments:** 1.2 $km.h^{-1}$ every 2 min up to 13.2 $km.h^{-1}$ (at 10th min of the test) increase of 2% every 2 min **Termination Criteria:** Physiological or volitional fatigue **Room Temperature:** 22.5 ± 1.0 ºC	**Exercise:** DWR **Intensity control:** Cadence **Initial intensity:** 48 cycles/min for 4 min (1 cycle = 2 steps) **Increments**: 66 cycles/min in the second stage and thereafter 3-4 cycles/min every 2 min **Termination Criteria:** When subjects fell behind the cadence, or when their physiological responses did not increase in response to the higher cadence, they were strongly encouraged

	Height: 171.8 ± 4.7 cm **Weight:** 75.4 ± 9.6 kg **BMI:** NR **Body fat percentage:** 22.7 ± 6.5%		to complete at least another full minute. They had been previously instructed to “go all out” during this final minute. **Water Temperature:** 32.5 ± 0.2 ºC
Nakanishi et al. [53]	Twenty young men **Age:** 28.0 ± 9.2 years **Height:** 172 ± 6.9 cm **Weight:** 67.1 ± 11.8 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** 9.6 $km.h^{-1}$ and 0% inclination for 4 min **Increments:** 1.2 $km.h^{-1}$ every 2 min up to 13.2 $km.h^{-1}$ (at 10th min of the test) increase of 2% every 2 min **Termination Criteria:** Physiological or volitional fatigue **Room Temperature:** 22.5 ± 1.0 ºC	**Exercise:** DWR **Intensity control:** Cadence **Initial intensity:** 48 cycles/min for 4 min (1 cycle = 2 steps) **Increments:** 66 cycles/min in the second stage and thereafter 3-4 cycles/min every 2 min **Termination Criteria:** When subjects fell behind the cadence, or when their physiological responses did not increase in response to the higher cadence, they were strongly encouraged to complete at least another full minute. They had been previously instructed to “go all out” during this final minute. **Water Temperature:** 32.5 ± 0.2 ºC
Phillips et al. [55]	Twenty overweight women **Age:** 48.0 ± 7.1 years **Height:** 162.2 ± 5.5 cm **Body mass:** 78.7 ± 12.0 kg **BMI:** 29.9 ± 4.0 $kg.m^{-2}$ **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Inclination **Initial intensity:** Individualized comfortable speed ranging from 4.1 to 6.0 $km.h^{-1}$ for 3 min **Increments:** 1% every 1 min **Termination Criteria:** Exhaustion **Room Temperature:** NR	**Exercise:** DWR **Intensity control:** Load increase **Initial intensity:** 0.57 kg **Increments:** 0.57 kg every 1 min **Termination Criteria:** Unable to maintain the bucket suspended **Water Temperature:** 29 ºC
Tiggemann et al. [45]	Five young women **Age:** 22.2 ± 1.3 years **Height:** 160.60 ± 5.59 cm **Weight:** 55.42 ± 8.26 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed **Initial intensity:** 4 $km.h^{-1}$ with 1% inclination **Increments:** 1 $km.h^{-1}$ every 1 min **Termination Criteria:** Exhaustion **Room Temperature:** 26 ºC	**Exercise:** DWR **Intensity control:** Load increase **Initial intensity:** 500 g **Increments:** 250 g every 1 min **Termination Criteria:** Exhaustion **Water Temperature:** 32 ºC
		Ergometers protocols	
		Land	**Water**
Garzon et al. [46]	Thirty-three healthy young participants (women = 5) **Age:** 33 ± 10 years **Height:** 174 ± 6 cm **Weight:** 72 ± 9 **BMI:** 23.7 ± 2.5 **Body fat percentage:** NR	**Exercise:** Cycle ergometer **Intensity control:** Workload **Initial intensity:** 25 W **Increments:** 25 W every 1 min maintaining the cadence of 80 rpm **Termination Criteria:** Exhaustion or unable to maintain the cadence **Room Temperature:** 21 ºC	**Exercise:** Water cycling **Intensity control:** Cadence (rpm) **Initial intensity:** 40 rpm **Increments:** 10 rpm every 1 min up to 70 rpm. Subsequently, the cadence was increased by 5 rpm. **Termination Criteria:** Exhaustion or unable to maintain the cadence **Water Temperature:** 30 ºC **Water depth:** Xiphoid process

Giacomini et al. [44]	Sixteen healthy participants Men = 8 **Age:** 31.5 ± 8.2 years **Height:** 179 ± 7 cm **Weight:** 80.0 ± 8.3 kg **BMI:** NR **Body fat percentage:** NR Women = 8 **Age:** 31.9 ± 5.8 years **Height:** 163 ± 5 cm **Weight:** 57.5 ± 4.2 kg **BMI:** NR **Body fat percentage:** NR	**Exercise:** Cycle ergometer **Intensity control:** Workload **Initial intensity:** 50 W **Increments:** 15-30 W (depending on the fitness level of the subjects) every 1 min maintaining the cadence of 70-80 rpm **Termination Criteria:** Exhaustion **Room Temperature:** NR	**Exercise:** Water cycling **Intensity control:** Cadence (rpm) **Initial intensity:** 40 rpm **Increments:** 5 rpm every 2 min **Termination Criteria:** Unable to maintain the cadence **Water Temperature:** 25 ± 1 ºC **Water depth:** Hips and thighs
Greene et al. [48]	Forty-nine healthy participants (Women = 25) **Age:** 41 ± 14 years **Height:** 173.9 ± 8.8 cm **Weight:** 88.3 ± 18.5 **BMI:** 29.0 ± 5.5 kg.m^{-2} **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Speed **Initial intensity:** 3.2 km.h^{-1} and 0% inclination **Increments:** 1.6 km.h^{-1} every 3 min up to 11.3 km.h^{-1} **Termination Criteria:** Exhaustion or exercise protocol completion. **Room Temperature:** NR	**Exercise:** Aquatic TRE **Intensity control:** Speed and water jet. Five experimental sessions (at 0%, 25%, 50%, 75% and 100%), in which the jet resistance was held constant throughout all treadmill velocities. **Initial intensity:** 3.2 km.h^{-1} **Increments:** 1.6 km.h^{-1} every 3 min up to 11.3 km.h^{-1} **Termination Criteria:** Exhaustion or exercise protocol completion. **Water Temperature:** 32–34 ºC **Water depth:** Fourth intercostal space
Schaal et al. [25]	Fourteen male triathletes **Age:** 35.1 ± 9.8 years **Height:** 182.1 ± 6.1 cm **Weight:** 78.7 ± 11.3 kg **BMI:** 23.9 ± 2.9 kg.m^{-2} **Body fat percentage:** NR	**Exercise:** TRE **Intensity control:** Inclination **Initial intensity:** Individualized predetermined speed (11.3 ± 0.6 km.h^{-1}) **Increments:** 2% every 2 min **Termination Criteria:** Exhaustion **Room Temperature:** NR	**Exercise:** Aquatic TRE **Intensity control:** Speed and water jet **Initial intensity:** 11.6 ± 0.6 km.h^{-1} + 40% water jet **Increments:** 0.8 km.h^{-1} every 1 min for 4 min, then increased jets 10% every 1 min **Termination Criteria:** Exhaustion **Water Temperature:** 25.8 ± 3.63 ºC **Water depth:** Xiphoid process
Silvers et al. [50]	Twenty-three recreationally competitive runners Women (n = 11) **Age:** 22.1 ± 2.3 years **Height:** 167.1 ± 13.9 cm **Body mass:** 60.9 ± 7.9 kg **BMI:** NR **Body fat percentage:** NR Men (n = 12) **Age:** 24.8 ± 3.8 years **Height:** 178.9 ± 5.4 cm	**Exercise:** TRE **Intensity control:** Speed and inclination **Initial intensity:** Individualized predetermined speed (10.2 ± 2.0 km.h^{-1}) **Increments:** 0.8 km.h^{-1} every 1 min for 4–5 min, then increased grade 2% every 1 min **Termination Criteria:** Exhaustion **Room Temperature:** 24 ± 1.0 ºC	**Exercise:** Aquatic TRE **Intensity control:** Speed and water jet **Initial intensity:** 9.8 ± 1.6 km.h^{-1} + 40% water jet **Increments:** 0.8 km.h^{-1} every 1 min for 4–5 min, then increased jets 10% every 1 min **Termination Criteria:** Exhaustion **Water Temperature:** 28 ºC **Water depth:** Xiphoid process

	Body mass: 73.0 ± 5.4 kg **BMI:** NR **Body fat percentage:** NR		
Yazigi et al. [26]	Ten young men **Age:** 22 ± 1 years **Height:** NR **Weight:** NR **BMI:** 22.7 ± 2 $kg.m^{-2}$ **Body fat percentage:** 11 ± 4.5%	**Exercise:** Cycle ergometer **Intensity control:** Workload **Initial intensity:** 75 W **Increments:** 35 W every 3 min maintaining the cadence of 70 rpm **Termination Criteria:** Exhaustion or unable to maintain the cadence **Room Temperature:** NR	**Exercise:** Water cycling **Intensity control:** Cadence (rpm) **Initial intensity:** 50 rpm **Increments:** 10 rpm every 3 min up to 70 rpm. Subsequently, the cadence was increased by 5 rpm every 3 min. **Termination Criteria:** Exhaustion or unable to maintain the cadence **Water Temperature:** 27 and 31 ºC in two different sessions. **Water depth:** Xiphoid process

BMI body mass index, *CCS* cross-country skiing, *DWR* deep water running, *FK* forward kick, *h* hour, *JJ* jumping jack, *min* minutes, *NR* not reported, *SR* stationary running, *SWR* shallow water running, *TRE* treadmill, *UTM* underwater treadmill

3.3 Risk of Bias in Studies

Table 3 reports the risk of bias for the included studies. Twelve studies (42.86%) clearly defined the sample inclusion criteria, and only one (3.57%) study described the participants' inclusion criteria and the setting in detail. Twenty-five (89.29%) studies employed validly and reliably the exposure, and eight (28.57%) studies described how the health condition of participants was assessed. All studies (100%) measured validly and reliably the outcomes, and seven (25%) studies used and described an appropriate statistical analysis. Although 18 (64.29%) studies described that the order of the protocols was randomized, none described how this procedure was performed. Finally, 26 (92.86%) studies reported the interval time between protocols.

Table 3 Detailed analysis of the risk of bias for each included study.

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7*	Q8*
Alberton et al. [27]	?	×	✓	×	✓	✓	?	✓
Alberton et al. [28]	✓	×	✓	×	✓	✓	?	✓
Azevedo et al. [40]	?	×	×	×	✓	?	?	✓
Brown et al. [37]	?	×	✓	✓	✓	?	×	✓
Butts et al. [23]	?	×	✓	×	✓	?	×	✓
Chu et al. [41]	✓	×	✓	×	✓	?	?	✓
Conti et al. [38]	✓	×	×	×	✓	?	×	✓
Cuesta-Vargas et al. [56]	✓	×	✓	×	✓	?	×	✓
Dowzer et al. [43]	?	✓	×	×	✓	?	×	×
Frangolias and Rhodes [24]	✓	×	✓	×	✓	?	?	✓
Frangolias et al. [39]	✓	×	✓	×	✓	×	?	✓
Garzon et al. [46]	✓	×	✓	×	✓	?	?	✓
Gayda et al. [35]	✓	×	✓	?	✓	✓	×	✓
Giacomini et al. [44]	?	×	✓	×	✓	✓	?	✓
Greene et al. [48]	?	?	✓	✓	✓	?	?	?
Kanitz et al. [51]	?	×	✓	×	✓	?	?	✓
Kruel et al. [52]	?	×	✓	×	✓	✓	?	✓
Masumoto et al. [54]	?	×	✓	✓	✓	?	?	✓
Mercer and Jensen [49]	×	×	✓	×	✓	?	?	✓
Michaud et al. [36]	?	×	✓	×	✓	?	?	✓
Nagle et al. [29]	✓	?	✓	✓	✓	?	×	✓
Nakanishi et al. [53]	?	×	✓	✓	✓	?	×	✓
Nakanishi et al. [42]	?	×	✓	✓	✓	?	×	✓
Phillips et al. [55]	✓	?	✓	✓	✓	?	×	✓
Schaal et al. [25]	✓	×	✓	✓	✓	?	?	✓
Silvers et al. [50]	✓	×	✓	×	✓	?	?	✓
Tiggemann et al. [45]	?	×	✓	×	✓	✓	?	✓
Yazigi et al. [26]	?	×	✓	×	✓	✓	?	✓

Q1 Were the criteria for inclusion in the sample clearly defined?; *Q2* Were the study subjects and the setting described in detail?; *Q3* Was the exposure measured in a valid and reliable way?; *Q4* Were objective, standard criteria used for measurement of the condition?; *Q5* Were the outcomes measured in a valid and reliable way?; *Q6* Was appropriate statistical analysis used?; *Q7* Was the randomization method described in detail?; *Q8* Was the interval time between protocols described?; * additional criteria; ✓ indicates Yes; ✕ indicates No; ? indicates Unclear.

3.4 Oxygen Uptake

Pooled results indicated that the aquatic protocols presented lower VO_{2max} values compared with protocols on land, considering a MD of − 7.07 mL·kg^{-1}·min^{-1} (95% CI − 8.43 to − 5.70; n = 502; Fig. 2), with a substantial heterogeneity ($p < 0.001$; $I^2 = 71\%$). From the subgroup analysis, the aquatic non-ergometer protocols showed lower VO_{2max} values (MD − 7.95 mL·kg^{-1}·min^{-1}; 95% CI − 8.96 to − 6.94; n = 357) with a moderate heterogeneity ($p = 0.02$; $I^2 = 38\%$). However, considering the subgroup of the aquatic protocols with ergometers, heterogeneity remained substantial ($p < 0.001$; $I^2 = 85\%$) and there was no difference found between environments (MD − 2.36 mL·kg^{-1}·min^{-1}; 95% CI − 7.32 to 2.61; n = 145). For the VO_{2AT} parameter, pooled results indicated that the aquatic protocols presented lower values compared with protocols on land (MD − 6.19 mL·kg^{-1}·min^{-1}; 95% CI − 7.66 to − 4.73; n = 96; p for heterogeneity = 0.33; I^2 = 13%; Fig. 3). The subgroup analysis was not performed for VO_{2AT}, as studies with aquatic ergometers did not investigate this variable.

Study or Subgroup	Water Mean	Water SD	Water Total	Land Mean	Land SD	Land Total	Weight	Mean Difference IV, Random, 95% CI
1.1.1 Non-ergometer								
Alberton et al. 2013 [27]	30.6	5.7	9	39.3	3.7	9	3.0%	-8.70 [-13.14, -4.26]
Alberton et al. 2014 [28]	30.4	4.3	20	36	4.1	20	3.8%	-5.60 [-8.20, -3.00]
Azevedo et al. 2010[a] [40]	44.3	3.3	7	55.1	4.2	7	3.2%	-10.80 [-14.76, -6.84]
Azevedo et al. 2010[b] [40]	48.3	8.4	10	53.8	6	10	2.2%	-5.50 [-11.90, 0.90]
Brown et al. 1996[a] [37]	39.1	8.3	12	45.2	4.4	12	2.6%	-6.10 [-11.42, -0.78]
Brown et al. 1996[b] [37]	30.1	4.5	12	40.1	3.1	12	3.6%	-10.00 [-13.09, -6.91]
Butts et al. 1991[a] [23]	58.4	3.9	12	64.5	2.8	12	3.7%	-6.10 [-8.82, -3.38]
Butts et al. 1991[b] [23]	46.8	5.9	12	55.7	4.8	12	3.1%	-8.90 [-13.20, -4.60]
Chu et al. 2002[a] [41]	43.2	9.1	9	47.1	8.9	9	1.7%	-3.90 [-12.22, 4.42]
Chu et al. 2002[b] [41]	18	3	9	23.1	3.3	9	3.7%	-5.10 [-8.01, -2.19]
Conti et al. 2008[a] [38]	57.2	3.9	6	68.9	5.1	6	2.7%	-11.70 [-16.84, -6.56]
Conti et al. 2008[b] [38]	45.2	6.8	6	47.9	3.6	6	2.3%	-2.70 [-8.86, 3.46]
Dowzer et al. 1999 [43]	43.8	6.5	15	55.4	8.5	15	2.6%	-11.60 [-17.02, -6.18]
Frangolias and Rhodes 1995 [24]	54.6	5.2	13	59.7	6.4	13	3.0%	-5.10 [-9.58, -0.62]
Frangolias et al. 1996[a] [39]	53.5	3.5	6	63.8	3	6	3.3%	-10.30 [-13.99, -6.61]
Frangolias et al. 1996[b] [39]	53.8	5.4	16	58.8	6.2	16	3.2%	-5.00 [-9.03, -0.97]
Gayda et al. 2010 [35]	19.7	7.1	21	31	6.2	21	3.2%	-11.30 [-15.33, -7.27]
Kanitz et al. 2014 [51]	22.5	4.1	12	33.7	3.9	12	3.5%	-11.20 [-14.40, -8.00]
Kruel et al. 2013 [52]	34	3.9	9	39	3.4	9	3.5%	-5.00 [-8.38, -1.62]
Masumoto et al. 2018 [54]	48.9	5.7	11	59.2	5.6	11	2.9%	-10.30 [-15.02, -5.58]
Mercer and Jensen 1998 [49]	44	10	28	54	13	28	2.4%	-10.00 [-16.07, -3.93]
Michaud et al. 1995 [36]	55.8	4	6	63.1	3.6	6	3.1%	-7.30 [-11.61, -2.99]
Nagle et al. 2017 [29]	37.1	6.8	23	44.2	8.4	23	3.0%	-7.10 [-11.52, -2.68]
Nakanishi et al. 1999 [53]	41	8.7	20	51.8	9.2	20	2.6%	-10.80 [-16.35, -5.25]
Nakanishi et al. 1999[a] [42]	39	7.8	14	49.5	7.6	14	2.5%	-10.50 [-16.20, -4.80]
Nakanishi et al. 1999[b] [42]	30.2	7.1	14	41.3	8	14	2.5%	-11.10 [-16.70, -5.50]
Phillips et al. 2008 [55]	22.5	4.9	20	27.7	4.7	20	3.6%	-5.20 [-8.18, -2.22]
Tiggemann et al. 2007 [45]	30.3	4.8	5	38.9	3.2	5	2.7%	-8.60 [-13.66, -3.54]
Subtotal (95% CI)			**357**			**357**	**83.3%**	**-7.95 [-8.96, -6.94]**
Heterogeneity: Tau² = 2.65; Chi² = 43.53, df = 27 (P = 0.02); I² = 38%								
Test for overall effect: Z = 15.40 (P < 0.00001)								
1.1.2 Ergometer								
Garzon et al. 2017 [46]	33.1	9.1	33	46.3	9.2	33	3.0%	-13.20 [-17.62, -8.78]
Giacomini et al. 2009 [44]	41.2	4.8	16	38.8	5.8	16	3.3%	2.40 [-1.29, 6.09]
Greene et al. 2011 [48]	30.8	8.5	49	30.1	8.6	49	3.5%	0.70 [-2.69, 4.09]
Schaal et al. 2012 [25]	52.5	7.5	14	53	6.9	14	2.6%	-0.50 [-5.84, 4.84]
Silvers et al. 2007 [50]	52.8	7.7	23	52.5	8.4	23	2.9%	0.30 [-4.36, 4.96]
Yazigi et al. 2013 [26]	57.2	11.9	10	62.2	10.1	10	1.4%	-5.00 [-14.67, 4.67]
Subtotal (95% CI)			**145**			**145**	**16.7%**	**-2.36 [-7.32, 2.61]**
Heterogeneity: Tau² = 31.41; Chi² = 34.08, df = 5 (P < 0.00001); I² = 85%								
Test for overall effect: Z = 0.93 (P = 0.35)								
Total (95% CI)			**502**			**502**	**100.0%**	**-7.07 [-8.43, -5.70]**
Heterogeneity: Tau² = 11.04; Chi² = 114.79, df = 33 (P < 0.00001); I² = 71%								
Test for overall effect: Z = 10.14 (P < 0.00001)								
Test for subgroup differences: Chi² = 4.68, df = 1 (P = 0.03), I² = 78.6%								

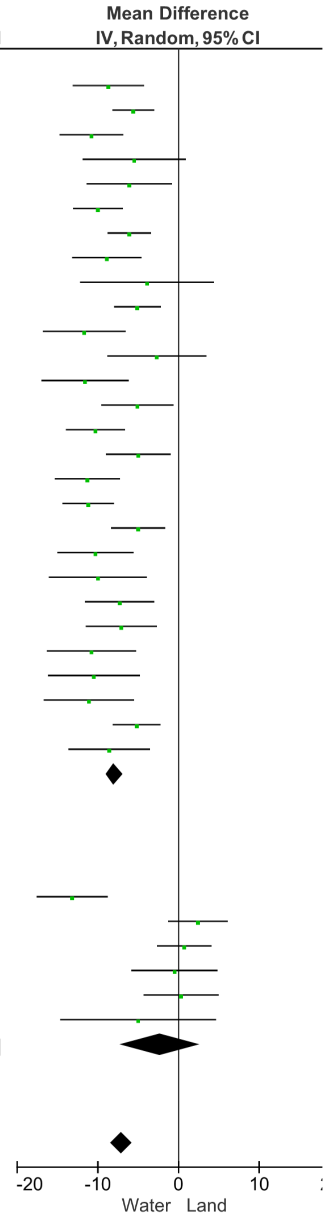

Fig. 2 Random-effects meta-analysis of maximal oxygen uptake in aquatic protocols compared to land protocols. Subgroup analysis was based on studies organized from protocols without ergometers and studies organized from protocols with ergometers. *CI* confidence interval, *df* degrees of freedom, *N* sample size, *SD* standard deviation

	Water			Land				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Alberton et al. 2013 [27]	21.7	5	9	30	3.4	9	12.1%	-8.30 [-12.25, -4.35]
Alberton et al. 2014 [28]	22.3	4.2	20	28.3	3.8	20	25.7%	-6.00 [-8.48, -3.52]
Azevedo et al. 2010[a] [40]	31.9	7.4	7	41	4.1	7	5.2%	-9.10 [-15.37, -2.83]
Azevedo et al. 2010[b] [40]	36.1	4.8	10	40.4	6.2	10	8.3%	-4.30 [-9.16, 0.56]
Frangolias and Rhodes 1995 [24]	42.8	5.1	13	46.3	6.4	13	9.8%	-3.50 [-7.95, 0.95]
Frangolias et al. 1996[b] [39]	42.6	4.6	16	46.7	4.7	16	17.1%	-4.10 [-7.32, -0.88]
Kanitz et al. 2014 [51]	18.7	4.8	12	28.1	5.3	12	11.6%	-9.40 [-13.45, -5.35]
Kruel et al. 2013 [52]	26.3	4.7	9	33	4.6	9	10.4%	-6.70 [-11.00, -2.40]
Total (95% CI)			**96**			**96**	**100.0%**	**-6.19 [-7.66, -4.73]**

Heterogeneity: Tau² = 0.57; Chi² = 8.02, df = 7 (P = 0.33); I² = 13%
Test for overall effect: Z = 8.29 (P < 0.00001)

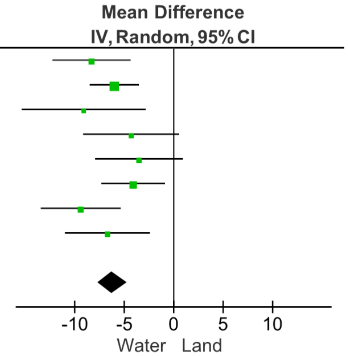

Fig. 3 Random-effects meta-analysis of oxygen uptake corresponding to anaerobic threshold in aquatic protocols compared to land protocols. *CI* confidence interval, *df* degrees of freedom, *N* sample size, *SD* standard deviation

3.5 Heart Rate

Pooled results indicated that the aquatic protocols presented lower HR_{max} values compared with protocols on land, considering a MD of − 11.71 bpm (95% CI − 13.84 to − 9.58; n = 503; Fig. 4), with a substantial heterogeneity ($p < 0.001$; $I^2 = 66\%$). From the subgroup analysis, pooled results indicated that the HR_{max} values were lower in the aquatic non-ergometer protocols compared with land protocols (MD − 13.39 bpm; 95% CI − 15.24 to − 11.55; n = 358), with a moderate heterogeneity ($p < 0.001$; $I^2 = 42\%$). For studies employing aquatic protocols with ergometers, there was no difference between environments (MD = − 4.03; 95% CI − 8.46 to 0.41; n = 145), and the heterogeneity remained substantial ($p = 0.03$; $I^2 = 60\%$). Considering studies included in the meta-analysis of HR_{AT} (Fig. 5), pooled results indicated that the aquatic protocols presented lower HR_{AT} values compared with protocols on land by − 15.29 bpm (95% CI − 19.05 to − 11.53; n = 87; p for heterogeneity = 0.86; $I^2 = 0\%$). Studies with aquatic ergometers did not investigate the HR_{AT}.

Study or Subgroup	Water Mean	Water SD	Water Total	Land Mean	Land SD	Land Total	Weight	Mean Difference IV, Random, 95% CI
1.2.1 Non-ergometer								
Alberton et al. 2014 [28]	184	9	20	191	7	20	3.8%	-7.00 [-12.00, -2.00]
Azevedo et al. 2010[a] [40]	172	13	7	186	11	7	1.8%	-14.00 [-26.62, -1.38]
Azevedo et al. 2010[b] [40]	177	11	10	186	9	10	2.6%	-9.00 [-17.81, -0.19]
Brown et al. 1996[a] [37]	184	8	12	196	5	12	3.7%	-12.00 [-17.34, -6.66]
Brown et al. 1996[b] [37]	174	7	12	195	5	12	3.8%	-21.00 [-25.87, -16.13]
Butts et al. 1991[a] [23]	183	6	12	193	6	12	3.9%	-10.00 [-14.80, -5.20]
Butts et al. 1991[b] [23]	180	8	12	189	9	12	3.2%	-9.00 [-15.81, -2.19]
Chu et al. 2002[a] [41]	182	9	9	192	9	9	2.8%	-10.00 [-18.32, -1.68]
Chu et al. 2002[b] [41]	156	11	9	167	10	9	2.4%	-11.00 [-20.71, -1.29]
Conti et al. 2008[a] [38]	177	7	6	191	8	6	2.7%	-14.00 [-22.51, -5.49]
Conti et al. 2008[b] [38]	182	9	6	185	7	6	2.6%	-3.00 [-12.12, 6.12]
Cuesta-Vargas et al. 2009 [56]	175	9	10	190	5	10	3.4%	-15.00 [-21.38, -8.62]
Dowzer et al. 1999 [43]	159	17	15	176	12	15	2.2%	-17.00 [-27.53, -6.47]
Frangolias and Rhodes 1995 [24]	175	12	13	190	11	13	2.6%	-15.00 [-23.85, -6.15]
Frangolias et al. 1996[a] [39]	174	10	6	191	9	6	2.2%	-17.00 [-27.76, -6.24]
Frangolias et al. 1996[b] [39]	173	14	16	188	13	16	2.5%	-15.00 [-24.36, -5.64]
Gayda et al. 2010 [35]	138	11	21	154	15	21	2.9%	-16.00 [-23.96, -8.04]
Kanitz et al. 2014 [51]	174	9	12	190	5	12	3.5%	-16.00 [-21.83, -10.17]
Kruel et al. 2013 [52]	187	7	9	196	4	9	3.7%	-9.00 [-14.27, -3.73]
Masumoto et al. 2018 [54]	174	10	11	191	7	11	3.1%	-17.00 [-24.21, -9.79]
Mercer and Jensen 1998 [49]	177	9	28	190	8	28	4.0%	-13.00 [-17.46, -8.54]
Michaud et al. 1995 [36]	169	13	6	184	6	6	2.0%	-15.00 [-26.46, -3.54]
Nagle et al. 2017 [29]	181	11	23	191	11	23	3.4%	-10.00 [-16.36, -3.64]
Nakanishi et al. 1999 [53]	172	14	20	191	9	20	3.1%	-19.00 [-26.29, -11.71]
Nakanishi et al. 1999[a] [42]	169	15	14	194	7	14	2.7%	-25.00 [-33.67, -16.33]
Nakanishi et al. 1999[b] [42]	158	20	14	183	13	14	1.8%	-25.00 [-37.50, -12.50]
Phillips et al. 2008 [55]	159	16	20	170	12	20	2.7%	-11.00 [-19.77, -2.23]
Tiggemann et al. 2007 [45]	185	10	5	195	9	5	1.9%	-10.00 [-21.79, 1.79]
Subtotal (95% CI)			**358**			**358**	**80.9%**	**-13.39 [-15.24, -11.55]**
Heterogeneity: Tau² = 9.61; Chi² = 46.66, df = 27 (P = 0.01); I² = 42%								
Test for overall effect: Z = 14.26 (P < 0.00001)								
1.2.2 Ergometer								
Garzon et al. 2017 [46]	167	12	33	177	14	33	3.4%	-10.00 [-16.29, -3.71]
Giacomini et al. 2009 [44]	172	8	16	169	10	16	3.4%	3.00 [-3.27, 9.27]
Greene et al. 2011 [48]	167	16	49	171	16	49	3.4%	-4.00 [-10.34, 2.34]
Schaal et al. 2012 [25]	173	11	14	185	13	14	2.6%	-12.00 [-20.92, -3.08]
Silvers et al. 2007 [50]	189	10	23	190	11	23	3.5%	-1.00 [-7.08, 5.08]
Yazigi et al. 2013 [26]	187	11	10	189	7	10	2.8%	-2.00 [-10.08, 6.08]
Subtotal (95% CI)			**145**			**145**	**19.1%**	**-4.03 [-8.46, 0.41]**
Heterogeneity: Tau² = 18.18; Chi² = 12.49, df = 5 (P = 0.03); I² = 60%								
Test for overall effect: Z = 1.78 (P = 0.08)								
Total (95% CI)			**503**			**503**	**100.0%**	**-11.71 [-13.84, -9.58]**
Heterogeneity: Tau² = 24.59; Chi² = 95.73, df = 33 (P < 0.00001); I² = 66%								
Test for overall effect: Z = 10.77 (P < 0.00001)								
Test for subgroup differences: Chi² = 14.62, df = 1 (P = 0.0001), I² = 93.2%								

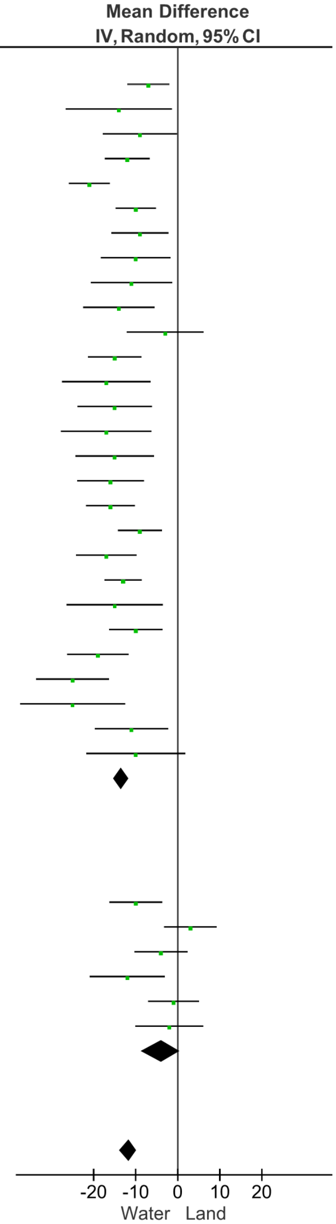

Fig. 4 Random-effects meta-analysis of maximal heart rate in aquatic protocols compared to land protocols. Subgroup analysis was based on studies organized from protocols without ergometers and studies organized from protocols with ergometers. *CI* confidence interval, *df* degrees of freedom, *N* sample size, *SD* standard deviation

Study or Subgroup	Water Mean	Water SD	Water Total	Land Mean	Land SD	Land Total	Weight	Mean Difference IV, Random, 95% CI
Alberton et al. 2014 [28]	157	15	20	175	10	20	22.7%	-18.00 [-25.90, -10.10]
Azevedo et al. 2010[a] [40]	149	22	7	163	19	7	3.1%	-14.00 [-35.53, 7.53]
Azevedo et al. 2010[b] [40]	151	14	10	161	15	10	8.8%	-10.00 [-22.72, 2.72]
Frangolias and Rhodes 1995 [24]	152	12	13	165	11	13	18.1%	-13.00 [-21.85, -4.15]
Frangolias et al. 1996[b] [39]	150	13	16	163	10	16	21.9%	-13.00 [-21.04, -4.96]
Kanitz et al. 2014 [51]	152	18	12	172	6	12	12.3%	-20.00 [-30.74, -9.26]
Kruel et al. 2013 [52]	168	13	9	185	9	9	13.3%	-17.00 [-27.33, -6.67]
Total (95% CI)			**87**			**87**	**100.0%**	**-15.29 [-19.05, -11.53]**

Heterogeneity: Tau² = 0.00; Chi² = 2.54, df = 6 (P = 0.86); I² = 0%
Test for overall effect: Z = 7.97 (P < 0.00001)

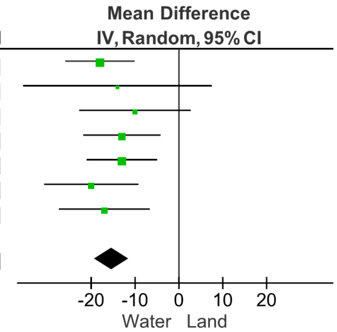

Fig. 5 Random-effects meta-analysis of heart rate corresponding to anaerobic threshold in aquatic protocols compared to land protocols. *CI* confidence interval, *df* degrees of freedom, *N* sample size, *SD* standard deviation

3.6 Rating of Perceived Exertion

Considering the studies included in the meta-analysis of RPE_{max} (Fig. 6), there was no difference between aquatic and land protocols (SMD: 0.01; 95% CI– 0.16 to 0.18; n = 299; p for heterogeneity = 0.39; I^2 = 6%). Likewise, from the subgroup analysis, there was no difference between environments for both aquatic non-ergometer protocols (SMD: 0.02; 95% CI − 0.19 to 0.24; n = 213; p for heterogeneity = 0.25, I^2 = 18%) and ergometer protocols (SMD: 0.03; 95% CI − 0.33 to 0.27; n = 86; p for heterogeneity = 0.71; I^2 = 0%). Considering the studies included in the meta-analysis of RPE_{AT} (Fig. 7), there was no difference found between aquatic and land protocols (MD: − 0.67; 95% CI − 1.35 to 0.02; n = 55; p for heterogeneity = 0.46; I^2 = 0%). Studies with aquatic ergometers did not analyze the RPE_{AT}.

Study or Subgroup	Water Mean	Water SD	Water Total	Land Mean	Land SD	Land Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.3.1 Non-ergometer								
Alberton et al. 2013 [27]	18.9	0.4	9	18.9	0.3	9	3.2%	0.00 [-0.92, 0.92]
Alberton et al. 2014 [28]	18.8	0.5	20	18.9	0.3	20	6.8%	-0.24 [-0.86, 0.38]
Azevedo et al. 2010[a] [40]	19	1	7	18	2	7	2.4%	0.59 [-0.49, 1.67]
Azevedo et al. 2010[b] [40]	19	1	10	18	2	10	3.4%	0.61 [-0.30, 1.51]
Brown et al. 1996[a] [37]	18	2	12	19	2	12	4.1%	-0.48 [-1.30, 0.33]
Brown et al. 1996[b] [37]	18	2	12	19	1	12	4.0%	-0.61 [-1.43, 0.21]
Frangolias and Rhodes 1995 [24]	20	2	13	20	2	13	4.6%	0.00 [-0.77, 0.77]
Frangolias et al. 1996[a] [39]	20	2	6	20	2	6	2.2%	0.00 [-1.13, 1.13]
Frangolias et al. 1996[b] [39]	20	2	16	20	2	16	5.5%	0.00 [-0.69, 0.69]
Masumoto et al. 2018 [54]	17.8	1.9	11	18.4	1.3	11	3.8%	-0.35 [-1.20, 0.49]
Michaud et al. 1995 [36]	9	2.4	6	9	2.4	6	2.2%	0.00 [-1.13, 1.13]
Nagle et al. 2017 [29]	9.6	0.8	23	8.5	1.6	23	7.1%	0.85 [0.25, 1.46]
Nakanishi et al. 1999 [53]	9.6	0.8	20	9.7	0.7	20	6.8%	-0.13 [-0.75, 0.49]
Nakanishi et al. 1999[a] [42]	9.7	0.6	14	9.3	0.9	14	4.7%	0.51 [-0.25, 1.26]
Nakanishi et al. 1999[b] [42]	9.2	1.1	14	9.6	0.7	14	4.8%	-0.42 [-1.17, 0.33]
Phillips et al. 2008 [55]	17	2	20	17	1	20	6.8%	0.00 [-0.62, 0.62]
Subtotal (95% CI)			**213**			**213**	**72.3%**	**0.02 [-0.19, 0.24]**
Heterogeneity: Tau² = 0.03; Chi² = 18.30, df = 15 (P = 0.25); I² = 18%								
Test for overall effect: Z = 0.18 (P = 0.85)								
1.3.2 Ergometer								
Greene et al. 2011 [48]	17	2	49	17	2	49	15.1%	0.00 [-0.40, 0.40]
Schaal et al. 2012 [25]	18.9	1	14	18.7	1.4	14	4.9%	0.16 [-0.58, 0.90]
Silvers et al. 2007 [50]	18.4	1.4	23	18.7	1.3	23	7.7%	-0.22 [-0.80, 0.36]
Subtotal (95% CI)			**86**			**86**	**27.7%**	**-0.03 [-0.33, 0.27]**
Heterogeneity: Tau² = 0.00; Chi² = 0.68, df = 2 (P = 0.71); I² = 0%								
Test for overall effect: Z = 0.21 (P = 0.83)								
Total (95% CI)			**299**			**299**	**100.0%**	**0.01 [-0.16, 0.18]**
Heterogeneity: Tau² = 0.01; Chi² = 19.07, df = 18 (P = 0.39); I² = 6%								
Test for overall effect: Z = 0.08 (P = 0.93)								
Test for subgroup differences: Chi² = 0.08, df = 1 (P = 0.78), I² = 0%								

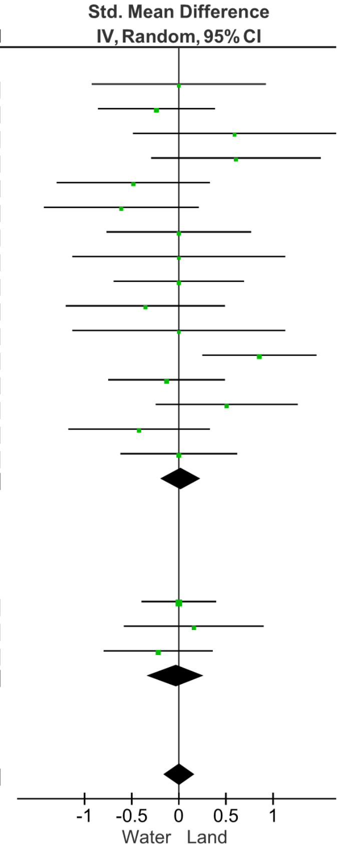

Fig. 6 Random-effects meta-analysis of maximal rating of perceived exertion in aquatic protocols compared to land protocols. Subgroup analysis was based on studies organized from protocols without ergometers and studies organized from protocols with ergometers. *CI* confidence interval, *df* degrees of freedom, *N* sample size, *SD* standard deviation

Study or Subgroup	Water Mean	Water SD	Water Total	Land Mean	Land SD	Land Total	Weight	Mean Difference IV, Random, 95% CI
Alberton et al. 2013 [27]	16	1.3	9	15.6	2.1	9	18.0%	0.40 [-1.21, 2.01]
Azevedo et al. 2010[a] [40]	13	1	7	13	2	7	17.1%	0.00 [-1.66, 1.66]
Azevedo et al. 2010[b] [40]	13	2	10	14	2	10	15.3%	-1.00 [-2.75, 0.75]
Frangolias and Rhodes 1995 [24]	12	2	13	13	2	13	19.8%	-1.00 [-2.54, 0.54]
Frangolias et al. 1996[b] [39]	12.1	1.6	16	13.4	2	16	29.8%	-1.30 [-2.55, -0.05]
Total (95% CI)			**55**			**55**	**100.0%**	**-0.67 [-1.35, 0.02]**
Heterogeneity: Tau² = 0.00; Chi² = 3.60, df = 4 (P = 0.46); I² = 0%								
Test for overall effect: Z = 1.91 (P = 0.06)								

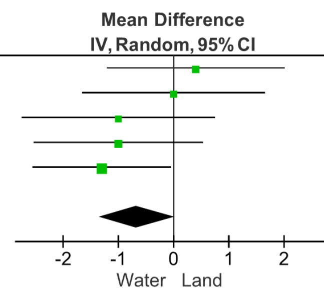

Fig. 7 Random-effects meta-analysis of rating of perceived exertion corresponding to anaerobic threshold in aquatic protocols compared to land protocols. *CI* confidence interval, *df* degrees of freedom, *N* sample size, *SD* standard deviation

4. DISCUSSION

The main aim of this review was to compare VO_2, HR, and RPE parameters (maximal and associated at the anaerobic threshold) between incremental protocols performed in aquatic and land environments. The main findings of the present study were the lower values during protocols performed in the aquatic environment compared with the land environment for VO_{2max} (MD = − 7.07 $mL \cdot kg^{-1} \cdot min^{-1}$) and VO_{2AT} (MD = − 6.19 $mL \cdot kg^{-1} \cdot min^{-1}$), as well as for HR_{max} (MD = − 11.71 bpm) and HR_{AT} (MD = − 15.29 bpm). However, no difference was observed between protocols for the RPE_{max} (SMD = 0.01) and RPE_{AT} (MD = − 0.67).

The lower HR values in the aquatic environment, compared to land, at maximal and associated at the anaerobic threshold can be attributed to physiological alterations in response to specific physical properties of water. The hydrostatic pressure acting on the body induces translocation of blood from the dependent limbs to the chest and increased plasma volume due to transcapillary autotransfusion of fluid from the cells [57, 58]. Moreover, the high heat conductivity of water can significantly influence human function in the aquatic environment [59, 60]. These mechanisms augment intrathoracic blood volume, increasing cardiac end diastolic volume, stroke volume, and cardiac output due to increased end-diastolic cardiac fiber length and reducing the HR and total peripheral resistance [14]. In addition, the increased venous return and atrial stretch lead to the attenuated secretion of anti-natriuretic and anti-diuretic hormones and increased atrial natriuretic peptide secretion, resulting in diuresis and natriuresis [14].

Regarding VO_2, it is first essential to understand that oxygen uptake is the product of cardiac output and arteriovenous difference. At rest, as a consequence of the increase in cardiac output in immersion, some studies observed similar VO_2 values between aquatic and land environments, while other studies found a slight increase [61, 62]. In this sense, for exercises performed on land, cardiac output increases because of greater metabolic demand. However, exercises performed in the aquatic environment reveal a higher cardiac output than on land, for an equivalent workload. Such cardiac output increase does not imply a proportional VO_2 as on land because the arteriovenous difference is lower in the water. Therefore, regardless of the blood redistribution occurrence for the active muscles, this cardiac output increased would not be expressively directed for these muscle groups, reflecting in a maximal and submaximal (i.e., anaerobic threshold) VO_2 significantly lower in the aquatic environment compared with the land environment, as the present results evidenced.

Regarding the RPE, no difference was observed between environments in maximal effort or the anaerobic threshold intensity. This result suggests comparable effort perception in relative and maximal intensity, independently of VO_2 and HR lower values in aquatic protocols. It may be attributed to RPE being defined as the subjective intensity of effort, tension, discomfort, and/or fatigue felt or experienced during aerobic and resistance exercises [63]. Thus, it should be considered that RPE is influenced by other factors such as muscular effort against water resistance and the cardiorespiratory component. It is noteworthy that even with no difference between water and land, contrary to other parameters, RPE has a positive linear relationship with the cardiorespiratory parameters, demonstrated by previous studies [10, 13, 64]. Therefore, the RPE is a valid measure to represent physiological changes as the effort increases within the same environment.

Using VO_2 and HR values measured on the land environment in the prescription of aquatic exercises may put individuals at greater cardiovascular risk, as it overestimates the intensity of training, considering the physiological changes resulting from immersion. Therefore, the present findings confirm the importance of specific maximal incremental tests in the aquatic environment to adequately determine the maximal and submaximal values for a suitable and safe prescription. However, RPE is interchangeable between environments and may be safely employed in different populations, especially in older individuals, who are frequently taking medications (e.g., beta-blockers) that can influence cardiovascular responses to exercise. These findings can be an advantage of using the RPE to prescribe intensity in the aquatic environment. This tool can avoid the direct influence of the physiological effects of immersion and guarantee a suitable intensity prescription. In addition, the prescription of exercise intensity based on the RPE has a greater external validity advantage, as it is a low-cost and straightforward tool of easy applicability for group classes in the aquatic environment. However, the extra time and effort are necessary to provide enough information before the beginning of training programs so that the method may be suitable for reaching the target intensity.

The physiological alterations caused by the hydrostatic pressure and high heat conductivity during thermoneutral immersion in the aquatic environment may also have important therapeutic repercussions. Obesity and cardiometabolic disorders are associated with sympathetic hyperactivity, with high levels of vasoconstrictor hormones, such as angiotensin II [65], contrary to the effects caused by immersion. In addition, the suppression of the renin-angiotensin system, also arising from immersion [66], is an interesting therapeutic target in individuals with excessive activation, a common characteristic in individuals with obesity and type 2 diabetes [67]. In addition, biomechanical aspects of aquatic exercises also may be considered as the low ground reaction force because the buoyancy provides a reduced impact in lower limbs compared with land [68, 69], which is a relevant characteristic for prescribing aerobic exercises for individuals with osteoarticular disorders. Collectively, the aquatic environment has therapeutic potential for training in these groups of clinical populations.

Another interesting result of our study is the subgroup analyzes for protocols with or without ergometers. The difference in cardiorespiratory parameters between environments only remains when summarized studies with non-ergometer protocols. We can speculate reasons for these differences based on ergometer use. In protocols with ergometer use, the overload is from water plus equipment mechanical load, while in non-ergometer protocols it is only the water resistance. Thus, the superposition of water resistance and mechanical load makes the physiological responses in the aquatic environment closer to those observed on land protocols. Furthermore, it is essential to highlight the specificity of ergometers in both environments, which makes the muscle groups involved during exercises more similar [70] and the physiological responses closer, resulting in a more negligible effect of the properties of water. However, the main modes of aquatic exercises performed in the vertical position (e.g., stationary water-based exercises, shallow water running/walking, deep water running) are not intended to simulate a protocol on land but to take advantage of the physical properties of water, which makes it necessary to create specific protocols to ensure the particularities of the environment.

We highlight that the heterogeneity between studies was substantial for VO_{2max} and HR_{max}, corresponding to 71% and 66%, respectively. However, the subgroup analysis showed that for protocols without ergometers, the heterogeneity was moderate (I^2 = 38%; p = 0.02 for VO_{2max} and I^2 = 42%; p = 0.01 for HR_{max}). This result indicates that the ergometer seems to be a source of heterogeneity, as varied ergometers were used (i.e., treadmills and cycle ergometers). Beyond the ergometers, although participants (i.e., sex, age, physical fitness) and protocol characteristics vary among studies, we believe that these factors are not relevant, as according to the results, it seems that the effect of the environment for protocols without ergometers are consistent in different participants.

Our results must be read in light of the primary studies' quality. We chose to report the Joanna Briggs Institute scale items separately instead of a single classification because not all items represent quality and bias of the same magnitude. Furthermore, the publication date of most studies precedes the reporting guidelines, and two items of the scale were not considered as they are not suitable for the design of included studies. We highlight that only one study adequately described the participant's inclusion criteria and setting. Out of 28 studies, seven described the statistical analysis satisfactorily, and no study reported if there was and/or how the randomization of the aquatic/land protocols sequence was carried out. Positively, all studies used and reported the parameters assessments, and most of them (i.e., 26 studies) reported the wash-out interval between protocols adequately. Future studies that intend to compare protocols in water and land per se or as a baseline assessment for trials would pay attention to the adequate reporting of methods.

Our study is not free of limitations. In addition to the limited quality of the primary studies, we did not include gray literature, and our eligibility had language restrictions. In addition, a high level of heterogeneity was present for the VO_{2max} and HR_{max} meta-analyses, and as such, results should be interpreted with caution. Although we tried to explore the causes of heterogeneity by performing subgroup analyses based on aquatic ergometers, other factors that were not investigated may have contributed to the high heterogeneity, such as mode of aquatic exercise, muscle groups involved in each protocol, and protocol characteristics. However, we believe this is the first study with a meta-analysis comparing cardiorespiratory and RPE parameters during incremental tests between land and aquatic environments. In addition, the present research encompassed a wide range of literature on the subject studied, including classic and current studies. Likewise, it included the main modes of aquatic exercise performed in the vertical position.

5. CONCLUSIONS

This review found that (1) cardiorespiratory parameters (i.e., VO_{2max}, VO_{2AT}, HR_{max}, and HR_{AT}) presented lower values during incremental protocols performed in the aquatic environment compared with land; (2) RPE_{max} and RPE_{AT} presented similar values during the protocols in both environments; and (3) subgroup analyses based on the use of the ergometers indicated differences in cardiorespiratory parameters between environments only for studies that employed aquatic protocols without ergometers, while no difference was observed for studies with aquatic ergometers. Our study reinforces the need to perform incremental tests in the aquatic environment when VO_2 and HR parameters are used for exercise prescription. At the same time, RPE seems an interchangeable measure of exercise intensity, with similar values during the protocols in both environments. These findings may prove valuable and helpful for coaches and researchers to prescribe water-based exercise programs more adequately according to preference and availability of resources.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40279-022-01687-y.

DECLARATIONS

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Author contributions All authors contributed to the conception and design of the review. LSA and CEB were responsible for the meta-analysis. LSA, CEB, and CLA drafted the manuscript. All authors edited and revised the manuscript and approved the final version of the manuscript.

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Electronic Supplementary Material

Cardiorespiratory Parameters Comparison Between Incremental Protocols Performed in Aquatic and Land Environments by Healthy Individuals: A Systematic Review and Meta-Analysis. Sports Medicine. Luana S. Andrade, Cintia E. Botton, Gabriela B. David, Stephanie S. Pinto, Mariana S. Häfele, Cristine L. Alberton. Corresponding author: andradelu94@gmail.com; Neuromuscular Assessment Laboratory, Physical Education School, Federal University of Pelotas, Pelotas, RS, Brazil.

Table 1 Complete database search strategy.

Database	Search Strategy
PubMed	#1 “water-based exercis*”[tiab] OR “water-based”[tiab] OR “aquatic exercis*”[tiab] OR aquatic OR “head-out water-based”[tiab] OR "water running"[tiab] OR “water walking”[tiab] OR “water cycling”[tiab] OR “aquatic cycling”[tiab] OR “deep water” OR “deep-water running”[tiab] OR “water-based aerobic exercise”[tiab] OR “water aerobic exercis*”[tiab] OR “underwater walking”[tiab] OR “underwater gait”[tiab] OR “aquajogging”[tiab] OR “hydrogymnastic*”[tiab] OR “water exercise” OR “water environment” OR “aquatic environment” #2 “Physical Exertion”[Mesh] OR “Exercise test”[Mesh] OR “Exercise testing” OR “Cardiopulmonary exercise test”[tiab] OR Cardiorespiratory[tiab] OR “Cardiorespiratory respons*”[tiab] OR “Exercise tolerance”[Mesh] OR “Exercise capacity”[tiab] OR “Maximal incremental test”[tiab] OR “Oxygen Consumption”[Mesh] OR “Oxygen uptake”[tiab] OR “Peak oxygen uptake”[tiab] OR “Maximal oxygen consumption”[tiab] OR “Maximal oxygen uptake”[tiab] OR “Graded exercise test”[tiab] OR “Maximal test”[tiab] OR “VO2”[tiab] OR “VO2 max”[tiab] OR “VO2 peak”[tiab] #3 Review[ti] OR Cohort[ti] OR Meta-analysis[ti] OR Synthesis[ti] OR Consensus[ti] #1 AND #2 NOT #3
Lilacs	“water-based exercise” OR “water based” OR “water exercise” OR "water running" OR “water walking” OR “water cycling” OR “deep-water running” OR “deep water OR “water-based aerobic exercise” OR “water aerobic exercise” OR “aquatic exercise” OR “aquatic cycling” OR aquatic OR “underwater walking” OR “underwater gait” OR (water AND exercise)
Embase	#1 'water based exercise'/exp OR 'deep water running'/exp OR 'aquatic exercise'/exp OR 'aquatic exercise' OR 'exercise, aquatic' OR 'underwater exercise'/exp OR 'water-based exercis*':ti,ab OR 'water based':ti,ab OR 'aquatic exercis*':ti,ab OR 'head-out water-based':ti,ab OR 'water running':ti,ab OR 'water walking':ti,ab OR 'water cycling':ti,ab OR 'aquatic cycling':ti,ab OR 'deep water':ti,ab OR 'water-based aerobic exercise':ti,ab OR 'water aerobic exercis*':ti,ab OR 'underwater walking':ti,ab OR 'underwater gait':ti,ab OR aquajogging:ti,ab OR hydrogymnastic*:ti,ab OR 'water exercise':ti,ab OR 'water environment':ti,ab #2 'exercise test'/exp OR 'effort test' OR 'exercise test' OR 'exercise testing' OR 'stress test' OR 'test, exercise' OR 'cardiopulmonary exercise test'/exp OR 'cardiopulmonary exercise test' OR 'cardiorespiratory response'/exp OR 'exercise tolerance'/exp OR 'exercise tolerance' OR 'tolerance, exercise' OR 'exercise tolerance test'/exp OR 'oxygen consumption'/exp OR 'o2 consumption' OR 'o2 uptake' OR 'oxygen consumption' OR 'oxygen demand' OR 'oxygen intake' OR 'oxygen requirement' OR 'oxygen uptake'

	OR 'oxygen utilization' OR 'peak oxygen uptake'/exp OR 'maximal oxygen consumption'/exp OR 'maximal oxygen uptake'/exp OR 'graded exercise test'/exp OR 'exercise testing':ti,ab OR 'cardiorespiratory fitness'/exp OR 'cardiorespiratory fitness' OR 'cardiorespiratory respons*':ti,ab OR 'exercise capacity':ti,ab OR 'maximal incremental test':ti,ab OR 'oxygen uptake':ti,ab OR 'maximal test':ti,ab OR vo2:ti,ab #3 'review':ti OR 'meta analysis':ti OR 'consensus':ti #1 AND #2 NOT #3
SPORTDiscus	#1 “water-based exercis*” OR “water-based” OR “head-out water-based” OR "water running" OR “water walking” OR “water cycling” OR “aquatic cycling” OR “deep-water running” OR “water-based aerobic exercise” OR “underwater walking” OR “underwater gait” OR “aquajogging” OR “hydrogymnastics” OR "AQUATIC exercises" OR "WATER aerobics" OR "AQUATIC exercises -- Therapeutic use” OR aquatic OR “deep water” OR OR “water exercise” OR “water environment” OR “aquatic environment” #2 “Exercise testing” OR “Cardiopulmonary exercise test” OR “Cardiorespiratory response” OR “Exercise capacity” OR “Maximal incremental test” OR “Oxygen uptake” OR “Peak oxygen uptake” OR “Maximal oxygen consumption” OR “Maximal oxygen uptake” OR “Graded exercise test” OR “Maximal test” OR “Maximal incremental test” OR “VO2” OR “VO2 max” OR “VO2 peak” OR "EXERCISE tests" OR "EXERCISE tolerance" OR "AEROBIC capacity" OR "CARDIOPULMONARY fitness measurement" OR "CARDIOPULMONARY fitness" OR "OXYGEN consumption" #3 TI (Review OR Cohort OR Meta-analysis OR Synthesis OR Consensus) #1 AND #2 NOT #3

ANEXOS

ANEXO I - Normas submissão

Journal of Strength & Conditioning Research

Information for Authors

The Journal of Strength and Conditioning Research (JSCR) is the official research journal of the National Strength and Conditioning Association (NSCA). The JSCR is published monthly. Membership in the NSCA is not a requirement for publication in the journal. JSCR publishes original investigations, systematic, and narrative reviews and meta-analyses, symposia, research notes, and technical and methodological reports contributing to the knowledge about strength and conditioning in sport and exercise. All manuscripts must be original works and present practical applications to the strength and conditioning professional or provide the basis for further applied research in the area. Manuscripts are subjected to a "double blind" peer review by at least two reviewers selected by Senior Associate Editors who are experts in the field. In some cases a "single blind" peer review may occur if a Senior Associate Editor is forced to serve as a reviewer. All editorial decisions are final and will be based on the quality, clarity, style, rank, and importance of the submission relative to the goals and objectives of the NSCA and the journal. Manuscripts can be rejected on impact alone as it relates to how the findings impact evidence based practice for strength and conditioning professionals, end users, and clinicians. Thus, it is important authors realize this when submitting manuscripts to the journal.

JSCR Senior Associate Editors will administratively REJECT a paper before review if it is deemed to have very low impact on practice, out of scope of the journal, poor experimental design, improperly formatted, and/or poorly written. Additionally, upon any revision the manuscript can be REJECTED if experimental issues and impact are not adequately addressed to reviewers, Senior Associate Editor, or Editor-in-Chief's satisfaction. The formatting of the manuscript is of great importance and manuscripts will be rejected if NOT PROPERLY formatted.

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JSCR publishes research on the effects of training programs on physical performance and function to the underlying biological basis for exercise performance as well as research from a number of disciplines attempting to gain insights about sport, sport demands, sport profiles, conditioning, and exercise such as biomechanics, exercise physiology, motor learning, nutrition, and psychology. A primary goal of JSCR is to provide an improved scientific basis for conditioning practices. JSCR will ONLY CONSIDER original manuscripts not currently under consideration from other journals. JSCR will NOT CONSIDER any manuscripts previously published on preprint servers or resubmitted manuscripts previously rejected by JSCR.

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Please Note

- Please make sure it is noted under the "Subjects" section in the METHODS that the study was approved by an Institutional Review Board (IRB) or Ethics Board and that the subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study. Additionally, if anyone who is under the age of 18 years of age is included, it should also be noted that parental or guardian signed consent was obtained. Please give the age range if the mean and SD suggest the subjects may have been under the age of 18 years. Authors are encouraged to include the IRB protocol or approval number.

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MANUSCRIPT PREPARATION

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The title page should include the manuscript title, brief running head, laboratory(s) where the research was conducted, authors' full name(s) spelled out with middle initials, department(s), institution(s), full mailing address of corresponding author including telephone and fax numbers, and email address, and disclosure of funding received for this work from any of the following organizations: National Institutes of Health (NIH); Wellcome Trust; Howard Hughes Medical Institute (HHMI); and other(s). Regarding authorship, each contributor should have played a role in at least two of the following areas: research concept and study design, literature review, data collection, data analysis and interpretation, statistical analyses, writing of the manuscript, or reviewing/editing a draft of the manuscript.

2. Blind Title Page

A second title page should be included that contains only the manuscript title. This will be used to send to the reviewers in our double blind process of review. Do not place identifying information in the Acknowledgment portion of the paper or anywhere else in the manuscript.

3. Abstract and Key Words

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4. Text

The text must contain the following sections with titles in ALL CAPS (i.e. INTRODUCTION, METHODS, RESULTS, DISCUSSION, PRACTICAL APPLICATIONS, ACKNOWLEDGMENTS, and REFERENCES) in this exact order:
A. Introduction. This section is a careful development of the hypotheses of the study leading to the clear purpose of the investigation. It should include the practical question that forms the basis of the study and how it may influence strength and conditioning practices. In most cases use no subheadings in this section and try to limit it to 4 - 6 concisely written paragraphs. The subject matter does not have to be exhaustively reviewed in this section.
B. Methods. Within the METHODS section, the following subheadings are required in the following order: "Experimental Approach to the Problem," where the author(s) show how their study design will be able to test the hypotheses developed in the introduction and give some basic rationales for the choices made for the independent and dependent variables used in the study; "Subjects," where the authors include the Institutional Review Board or Ethics Committee approval of their project and appropriate informed consent has been gained. Eligibility criteria for subject selection should be included in the manuscript. Authors should include relative descriptive information such as age, height, body mass, and when appropriate the training status and training history of the subjects, e.g. years of training or sport experience. When appropriate, dietary controls and supervision should be described. All subject characteristics that are not dependent variables of the study should be included in this section and not in the RESULTS; "Procedures," in this section the methods used are presented with the concept of "replication of the study" kept in mind. Authors should describe the research design used in the study. Training programs and testing methods used should be described in detail. Authors are strongly encouraged to include a Control group/condition when appropriate. If a Control group/condition is not used, authors MUST provide test-retest reliability coefficients of the measures used during protocols involving multiple testing periods. Test-retest reliability data should be generated from the authors' laboratory and not merely cited from literature obtained in other laboratories. Additionally, reviewers will look for experimental control for time of day, hydration, sleep and nutritional status. "Statistical Analyses," here is where you clearly state your statistical approach to the analysis of the data set(s). It is important that you include your alpha level for significance (e.g., $\rho \leq 0.05$). Please place your statistical power in the manuscript for the n size used and reliability of the dependent measures with intra-class correlations (ICC Rs). Additional subheadings can be used but should be limited. Authors should report effect sizes and confidence intervals when appropriate. Traditional statistical procedures must be used. The magnitude-based inference (MBI) approach may be used BUT ONLY IN CONJUNCTION with traditional methods.
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D. Discussion. Discuss the meaning of the results of your study in this section. Relate them to the literature that currently exists and make sure you bring the paper to completion with each of your hypotheses. Authors should emphasize the new and unique findings of the study. Conclusions should be supported by the data presented. Limit obvious statements like, ‘‘more research is needed.’’

E. Practical Applications. In this section, tell the ‘‘coach’’ or practitioner how your data can be applied and used. It should reflect the answer to the question posed in the Introduction. It is the distinctive characteristic of the JSCR and supports the mission of ‘‘Bridging the Gap’’ for the NSCA between the laboratory and the field practitioner. This section should be limited to 350 words or less.

5. References

All references must be alphabetized by surname of first author and numbered. References are cited in the text by numbers [e.g., (4,9)]. All references listed must be cited in the manuscript and referred to by number therein. For original investigations, please limit the number of references to fewer than 45 or explain why more are necessary. The Editorial Office reserves the right to ask authors to reduce the number of references in the manuscript. It is acceptable to cite a published Research Abstract ONLY if it is a sole source of information in that specific scientific area. JSCR forbids the citation of manuscripts published on preprint servers. For journal entries with 6 or more co-authors, please list the first 3 names followed by "et al." When citing chapters within an edited textbook, authors MUST specifically cite the chapter author names (not the editors). Authors must also include the chapter name and page range for all book references. Please check references carefully for accuracy. Changes to references at the proof stage, especially changes affecting the numerical order in which they appear, will result in author revision fees. For End Note Users, the software currently is using an older style of formatting for JSCR references. It is recommended that authors update the final reference list by either manually checking each reference to ensure proper formatting or updating their End Note software. To update the software, End Note users may edit "Output Styles" for JSCR and save the changes. Users may click "Citations" and "Author Lists" to edit "Author Separators" "and "Abbreviated Author List". This will allow users to remove the term "and" and use "et al." for referencing. Questions regarding End Note use or software editing are directed to Clarivate support at 1-800-336-4474. If using End Note please double-check citations and make sure journal article titles do not have all words capitalized and journal titles are abbreviated properly and italicized.

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Book

Lohman, TG. *Advances in Body Composition Assessment*. Champaign, IL: Human Kinetics, 1992.

Chapter in an edited book

Yahara, ML. The shoulder. In: *Clinical Orthopedic Physical Therapy*. J.K. Richardson and Z.A. Iglarsh, eds. Philadelphia: Saunders, 1994. pp. 159–199.

Software

Howard, A. Moments ½software_. University of Queensland, 1992.

Proceedings

Viru, A, Viru, M, Harris, R, Oopik, V, Nurmekivi, A, Medijainen, L, Timpmann, S. Performance capacity in middle-distance runners after enrichment of diet by creatine and creatine action on protein synthesis rate. In: Proceedings of the 2nd Maccabiah-Wingate International Congress of Sport and Coaching Sciences. G. Tenenbaum and T. Raz-Liebermann, eds. Netanya, Israel, Wingate Institute, 1993. pp. 22–30.

Dissertation/Thesis

Bartholmew, SA. Plyometric and vertical jump training.Master’s thesis, University of North Carolina, Chapel Hill, 1985.

6. Acknowledgments

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Figure legends should appear on a separate page, with each figure appearing on its own separate page. One set of figures should accompany each manuscript. Use only clearly delineated symbols and bars. Please do not mask the facial features of subjects in figures. Permission of the subject to use his/her likeness in the Journal should be included in each submission. Photo release forms may be downloaded from the Information for Authors page at https://journals.lww.com/nsca-jscr/pages/informationforauthors.aspx.

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Per the JSCR Editorial Board and to promote consistency and clarity of communication among all scientific journals, authors should use standard terms generally acceptable to the field of exercise science and sports science. Along with the American College of Sports Medicine’s Medicine and Science in Sport and Exercise, the JSCR Editorial Board endorses the use of the following terms and units.

The units of measurement shall be Systeme International d’Unite´ s (SI). Permitted exceptions to SI are heart rate—beats per min; blood pressure—mm Hg; gas pressure—mm Hg. Authors should refer to the British Medical Journal (1:1334 – 1336, 1978) and the Annals of Internal Medicine (106: 114 – 129, 1987) for the proper method to express other units or abbreviations. When expressing units, please locate the multiplication symbol midway between lines to avoid confusion with periods; e.g., $ml{\cdot}min^{-1}{\cdot}kg^{-1}$.

The basic and derived units most commonly used in reporting research in this Journal include the following: mass—gram (g) or kilogram (kg); force—newton (N); distance—meter (m), kilometer (km); temperature—degree Celsius (_C); energy, heat, work—joule (J) or kilojoule (kJ); power—watt (W); torque—newton-meter (N_m); frequency—hertz (Hz); pressure—pascal (Pa); time—second (s), minute (min), hour (h); volume—liter (L), milliliter (mL); and amount of a particular substance—mole (mol), millimole (mmol). Please note that the correct way to express body mass of the subjects is in kg and not "weight (lbs)" or "weight (kg)."

Selected conversion factors:

_ 1 N = 0.102 kg (force);
_ 1 J = 1 N_m = 0.000239 kcal = 0.102 kg_m;
_ 1 kJ = 1000 N_m = 0.239 kcal = 102 kg_m;
_ 1 W = 1 J_s-1 = 6.118 kg_m_min-1.

When using nomenclature for muscle fiber types please use the following terms. Muscle fiber types can be identified using histochemical or gel electrophoresis methods of classification. Histochemical staining of the ATPases is used to separate fibers into type I (slow twitch), type IIa (fast twitch) and type IIb (fast twitch) forms.Thework of Smerdu et. al (AJP 267:C1723, 1994) indicates that type IIb fibers contain type IIxmyosin heavy chain (gel electrophoresis fiber typing). For the sake of continuity and to decrease confusion on this point it is recommended that authors use IIx to designate what use to be called IIb fibers. Smerdu, V, Karsch-Mizrachi, I, Campione, M, Leinwand, L, and Schiaffino, S. Type IIx myosin heavy chain transcripts are expressed in type IIb fibers of human skeletal muscle. Am J Physiol 267 (6 Pt 1): C1723–1728, 1994.

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ANEXO II - Normas submissão

Sports Medicine

Instructions for Authors

Please read these instructions in conjunction with the "Additional Information for Authors" document. This document, together with other useful submission documentation, can be found by following the "Important Information for Authors" link:

Types of Papers

Please note:

There is no limit on the number of tables, figures or references that can accompany an article. Information that is relevant but not critical to understanding the article can be presented as supplementary information, which will be available online only. The word counts given below are to be treated as guides only. They do not include the abstract, references, figure legends or table captions. Sports Medicine does not specify a word limit for Original Research Articles.

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- Current Opinion. Word count approximately up to 3000. Places an area in perspective given that it is of current international interest and a consensus has not yet been reached; therefore, the arguments presented may be controversial, but at the same time must be balanced and rational.
- Leading Article. Word count up to 4000. Provides a short, balanced overview of the current state of development of an emerging area.
- Systematic Review. Word count up to 10,000. Collates all empirical evidence that fits pre-specified eligibility criteria to answer a specific research question. It uses explicit, systematic methods that are selected with a view to minimizing bias, thus providing reliable findings from which conclusions can be drawn and decisions made. Please follow the reporting guidelines of PRISMA.
- Original Research Article. Sports Medicine will consider high-quality original research with a strong link to clinical practice in the field of sport and exercise medicine.
- Letter to the Editor. Word count up to 1000. Comment on an article published recently in the journal; a response to the comments would normally be sought from the authors of the original article and published in the same issue, where possible.

The journal can publish a range of digital features alongside articles (including animated abstracts, video abstracts, slide decks, audio slides, instructional videos, infographics, podcasts, and animations), as well as plain language summaries (PLSs). These features are designed to increase visibility, readership, and the educational value of the article's content. As all such features are peer reviewed, it is preferable for this content to be submitted at article submission stage. However, digital features and PLSs can be submitted (and peer reviewed) after article acceptance if necessary; a fee is associated with submission at this stage to cover additional processing. Digital features and PLSs must provide an accurate representation of the article. For further information on digital features and PLSs, please see here for our Guidelines for digital features and plain language summaries:

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Internal Review by Editorial Staff: The journal editor will perform an initial appraisal of each manuscript. When submitting your paper, please include a covering letter that provides the article type, an outline of why the paper is important, a brief description of what is covered in the review/was found in the study, why the paper would be of interest to the journal's readership, and any other pertinent information. If your paper has been peer reviewed by another journal as part of a prior submission, please provide any previous editorial/referee comments and detail how these have been dealt with in the current submission; the journal editor will assess this information as part of the appraisal process.

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Manuscript Submission

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Please make sure your title page contains the following information.

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- A clear indication and an active e-mail address of the corresponding author
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Please provide an abstract of 150 to 250 words. The abstract should not contain any undefined abbreviations or unspecified references.

For life science journals only (when applicable)

- Trial registration number and date of registration for prospectively registered trials
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The following statements should be included under the heading "Statements and Declarations" for inclusion in the published paper. Please note that submissions that do not include relevant declarations will be returned as incomplete.

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- Use the equation editor or MathType for equations.
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Please use the decimal system of headings with no more than three levels.

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Abbreviations should be defined at first mention and used consistently thereafter.

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Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables.

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Always use footnotes instead of endnotes.

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Acknowledgments of people, grants, funds, etc. should be placed in a separate section on the title page. The names of funding organizations should be written in full.

References

Citation

Reference citations in the text should be identified by numbers in square brackets. Some examples:

1. Negotiation research spans many disciplines [3].
2. This result was later contradicted by Becker and Seligman [5].
3. This effect has been widely studied [1-3, 7].

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The entries in the list should be numbered consecutively.

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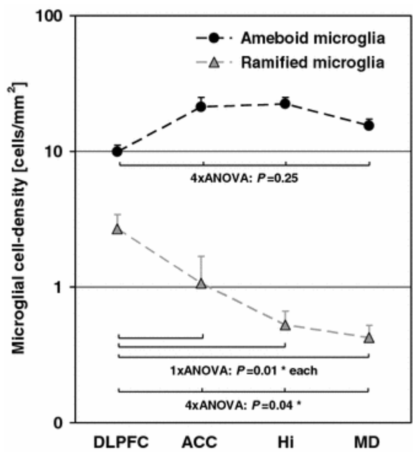

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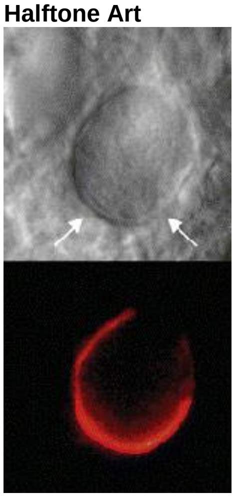

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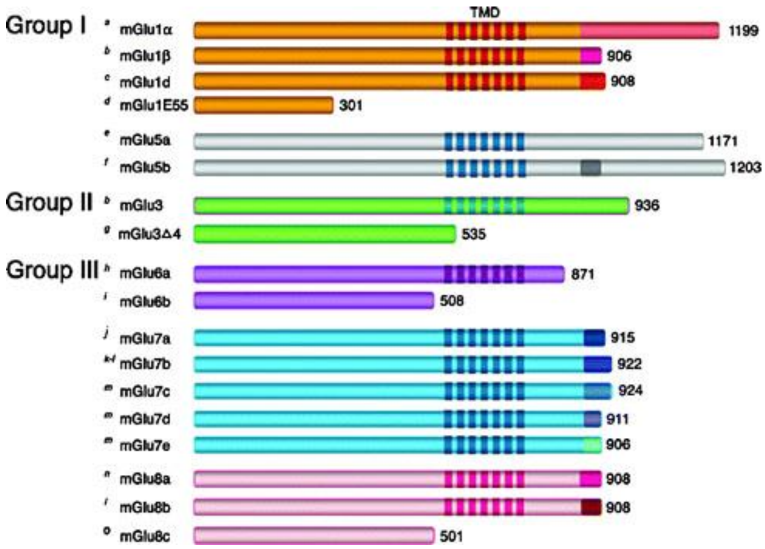

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If human cells are used, authors must declare in the manuscript: what cell lines were used by describing the source of the cell line, including when and from where it was obtained, whether the cell line has recently been authenticated and by what method. If cells were bought from a life science company the following need to be given in the manuscript: name of company (that provided the cells), cell type, number of cell line, and batch of cells.

It is recommended that authors check the NCBI database for misidentification and contamination of human cell lines. This step will alert authors to possible problems with the cell line and may save considerable time and effort.

Further information is available from the International Cell Line Authentication Committee (ICLAC).

Authors should include a statement that confirms that an institutional or independent ethics committee (including the name of the ethics committee) approved the study and that informed consent was obtained from the donor or next of kin.

Research Resource Identifiers (RRID)

Research Resource Identifiers (RRID) are persistent unique identifiers (effectively similar to a DOI) for research resources. This journal encourages authors to adopt RRIDs when reporting key biological resources (antibodies, cell lines, model organisms and tools) in their manuscripts.

Examples:

Organism: *Filip1$^{tm1a(KOMP)Wtsi}$* **RRID:MMRRC_055641-UCD**

Cell Line: RST307 cell line **RRID:CVCL_C321**

Antibody: Luciferase antibody DSHB Cat# LUC-3, **RRID:AB_2722109**

Plasmid: mRuby3 plasmid **RRID:Addgene_104005**

Software: ImageJ Version 1.2.4 **RRID:SCR_003070**

RRIDs are provided by the Resource Identification Portal. Many commonly used research resources already have designated RRIDs. The portal also provides authors links so that they can quickly register a new resource and obtain an RRID.

Clinical Trial Registration

The World Health Organization (WHO) definition of a clinical trial is "any research study that prospectively assigns human participants or groups of humans to one or more health-related interventions to evaluate the effects on health outcomes". The WHO defines health interventions as "A health intervention is an act performed for, with or on behalf of a person or population whose purpose is to assess, improve, maintain, promote or modify health, functioning or health conditions" and a health-related outcome is generally defined as a change in the health of a person or population as a result of an intervention.

To ensure the integrity of the reporting of patient-centered trials, authors must register prospective clinical trials (phase II to IV trials) in suitable publicly available repositories. For example www.clinicaltrials.gov or any of the primary registries that participate in the WHO International Clinical Trials Registry Platform.

The trial registration number (TRN) and date of registration should be included as the last line of the manuscript abstract.

For clinical trials that have not been registered prospectively, authors are encouraged to register retrospectively to ensure the complete publication of all results. The trial registration number (TRN), date of registration and the words 'retrospectively registered' should be included as the last line of the manuscript abstract.

Standards of reporting

Springer Nature advocates complete and transparent reporting of biomedical and biological research and research with biological applications. Authors are recommended to adhere to the minimum reporting guidelines hosted by the EQUATOR Network when preparing their manuscript.

Exact requirements may vary depending on the journal; please refer to the journal's Instructions for Authors.

Checklists are available for a number of study designs, including:

Randomised trials (CONSORT) and Study protocols (SPIRIT)

Observational studies (STROBE)

Systematic reviews and meta-analyses (PRISMA) and protocols (Prisma-P)

Diagnostic/prognostic studies (STARD) and (TRIPOD)

Case reports (CARE)

Clinical practice guidelines (AGREE) and (RIGHT)

Qualitative research (SRQR) and (COREQ)

Animal pre-clinical studies (ARRIVE)

Quality improvement studies (SQUIRE)

Economic evaluations (CHEERS)

Summary of requirements

The above should be summarized in a statement and placed in a 'Declarations' section before the reference list under a heading of 'Ethics approval'.

Examples of statements to be used when ethics approval has been obtained:

• All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Bioethics Committee of the Medical University of A (No. ...).

• This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University B (Date.../No. ...).

• Approval was obtained from the ethics committee of University C. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

• The questionnaire and methodology for this study was approved by the Human Research Ethics committee of the University of D (Ethics approval number: ...).

Examples of statements to be used for a retrospective study:

• Ethical approval was waived by the local Ethics Committee of University A in view of the retrospective nature of the study and all the procedures being performed were part of the routine care.

• This research study was conducted retrospectively from data obtained for clinical purposes. We consulted extensively with the IRB of XYZ who determined that our study did not need ethical approval. An IRB official waiver of ethical approval was granted from the IRB of XYZ.
• This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The Human Investigation Committee (IRB) of University B approved this study.
Examples of statements to be used when no ethical approval is required/exemption granted:
• This is an observational study. The XYZ Research Ethics Committee has confirmed that no ethical approval is required.
• The data reproduced from Article X utilized human tissue that was procured via our Biobank AB, which provides de-identified samples. This study was reviewed and deemed exempt by our XYZ Institutional Review Board. The BioBank protocols are in accordance with the ethical standards of our institution and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.
Authors are responsible for correctness of the statements provided in the manuscript. See also Authorship Principles. The Editor-in-Chief reserves the right to reject submissions that do not meet the guidelines described in this section.
Informed Consent
All individuals have individual rights that are not to be infringed. Individual participants in studies have, for example, the right to decide what happens to the (identifiable) personal data gathered, to what they have said during a study or an interview, as well as to any photograph that was taken. This is especially true concerning images of vulnerable people (e.g. minors, patients, refugees, etc) or the use of images in sensitive contexts. In many instances authors will need to secure written consent before including images.
Identifying details (names, dates of birth, identity numbers, biometrical characteristics (such as facial features, fingerprint, writing style, voice pattern, DNA or other distinguishing characteristic) and other information) of the participants that were studied should not be published in written descriptions, photographs, and genetic profiles unless the information is essential for scholarly purposes and the participant (or parent/guardian if the participant is a minor or incapable or legal representative) gave written informed consent for publication. Complete anonymity is difficult to achieve in some cases. Detailed descriptions of individual participants, whether of their whole bodies or of body sections, may lead to disclosure of their identity. Under certain circumstances consent is not required as long as information is anonymized and the submission does not include images that may identify the person.
Informed consent for publication should be obtained if there is any doubt. For example, masking the eye region in photographs of participants is inadequate protection of anonymity. If identifying characteristics are altered to protect anonymity, such as in genetic profiles, authors should provide assurance that alterations do not distort meaning.
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Consent and already available data and/or biologic material

Regardless of whether material is collected from living or dead patients, they (family or guardian if the deceased has not made a pre-mortem decision) must have given prior written consent. The aspect of confidentiality as well as any wishes from the deceased should be respected.

Data protection, confidentiality and privacy

When biological material is donated for or data is generated as part of a research project authors should ensure, as part of the informed consent procedure, that the participants are made aware what kind of (personal) data will be processed, how it will be used and for what purpose. In case of data acquired via a biobank/biorepository, it is possible they apply a broad consent which allows research participants to consent to a broad range of uses of their data and samples which is regarded by research ethics committees as specific enough to be considered "informed". However, authors should always check the specific biobank/biorepository policies or any other type of data provider policies (in case of non-bio research) to be sure that this is the case.

Consent to Participate

For all research involving human subjects, freely-given, informed consent to participate in the study must be obtained from participants (or their parent or legal guardian in the case of children under 16) and a statement to this effect should appear in the manuscript. In the case of articles describing human transplantation studies, authors must include a statement declaring that no organs/tissues were obtained from prisoners and must also name the institution(s)/clinic(s)/department(s) via which organs/tissues were obtained. For manuscripts reporting studies involving vulnerable groups where there is the potential for coercion or where consent may not have been fully informed, extra care will be taken by the editor and may be referred to the Springer Nature Research Integrity Group.

Consent to Publish

Individuals may consent to participate in a study, but object to having their data published in a journal article. Authors should make sure to also seek consent from individuals to publish their data prior to submitting their paper to a journal. This is in particular applicable to case studies. A consent to publish form can be found here. (Download docx, 36 kB)

Summary of requirements

The above should be summarized in a statement and placed in a 'Declarations' section before the reference list under a heading of 'Consent to participate' and/or 'Consent to publish'. Other declarations include Funding, Competing interests, Ethics approval, Consent, Data and/or Code availability and Authors' contribution statements.

Please see the various examples of wording below and revise/customize the sample statements according to your own needs.

Sample statements for **"Consent to participate"**:

Informed consent was obtained from all individual participants included in the study.

Informed consent was obtained from legal guardians.

Written informed consent was obtained from the parents.

Verbal informed consent was obtained prior to the interview.

Sample statements for **"Consent to publish"**:

The authors affirm that human research participants provided informed consent for publication of the images in Figure(s) 1a, 1b and 1c.

The participant has consented to the submission of the case report to the journal.

Patients signed informed consent regarding publishing their data and photographs.

Sample statements if identifying information about participants is available in the article:

Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

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