

Aquatic Exercise in Adults with Type 2 Diabetes Mellitus: An Updated Systematic Review of Clinical Trials

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Abstract

Objective: To analyze the acute responses and chronic effects of aquatic exercise programs in adults with type 2 diabetes mellitus (T2DM), considering glycated hemoglobin (HbA1c) and fasting blood glucose as the primary outcomes.

Materials and Methods: A systematic review was conducted in accordance with the PRISMA 2020 guidelines. The search was performed in PubMed, Web of Science, Scopus, and the Cochrane Library in February 2026. Clinical trials involving adults with T2DM who participated in structured aquatic exercise programs were included. Risk of bias was assessed using the ROBINS tool.

Results: Five studies met the inclusion criteria (n = 151). Three studies reported significant reductions in HbA1c, while three demonstrated decreases in blood glucose levels. The interventions ranged from 5 to 45 sessions, with moderate-to-vigorous intensity and a predominant frequency of three sessions per week.

Conclusions: Aquatic exercise is associated with improvements in glycemic control in adults with T2DM; however, the available evidence remains limited and heterogeneous.

Keywords: Physical activity, aquatic therapy, metabolic disorder, aquatic environment, glucose

Introduction

Type 2 diabetes mellitus (T2DM) is one of the leading causes of morbidity and mortality worldwide and represents a growing challenge for healthcare systems due to its high prevalence and the burden of associated cardiovascular, renal, and neurological complications (Basto-Abreu et al., 2023; International Diabetes Federation [IDF], 2024; World Health Organization, 2023). The International Diabetes Federation estimates that more than 580 million adults currently live with diabetes, with projections indicating a sustained increase over the coming decades (IDF, 2024). In Mexico, recent data from the 2022 National Health and Nutrition Survey (ENSANUT 2022) report a prevalence of 18.3%, confirming its significant epidemiological impact in Latin American settings (Basto-Abreu et al., 2023).

Glycemic control is a central objective in the management of T2DM, as sustained reductions in glycated hemoglobin (HbA1c) are associated with a lower risk of microvascular and macrovascular complications (American Diabetes Association [ADA], 2025; UK Prospective Diabetes Study [UKPDS] Group, 1998). Physical exercise is recognized as an essential non-pharmacological intervention, with consistent evidence supporting its effects on insulin sensitivity, peripheral glucose uptake, and metabolic regulation (Kanaley et al., 2022; Way et al., 2016).

Classic and contemporary meta-analyses have demonstrated that structured aerobic, resistance, or combined exercise programs significantly reduce HbA1c levels in individuals with T2DM (Umpierre et al., 2011; Kumar et al., 2019). In addition, recent reviews have confirmed improvements in fasting blood glucose, lipid profiles, and blood pressure in populations with metabolic syndrome and diabetes, reinforcing the role of exercise as a comprehensive cardiometabolic intervention (Galván et al., 2025).

Current clinical guidelines recommend regular moderate- to vigorous-intensity aerobic exercise complemented by resistance training as part of the standard therapeutic approach (Kanaley et al., 2022; American Diabetes Association [ADA], 2024). However, adherence to conventional land-based exercise programs may be compromised in individuals with obesity, musculoskeletal pain, or functional limitations, conditions that are

common among adults with T2DM. These mechanical barriers may limit sustained participation and reduce the effectiveness of interventions.

Aquatic exercise provides an environment with distinctive physical properties that modify biomechanical loading and physiological responses to exercise. Buoyancy reduces compressive forces on the joints, while hydrostatic pressure and water viscosity allow exercise intensity to be adjusted with lower structural impact (Becker, 2009; Tomescu et al., 2025). In vivo measurements have demonstrated reduced joint forces at the hip and knee during activities performed in immersion compared with land-based conditions (Pöyhönen et al., 1999). In adults with obesity, both aquatic and land-based exercise have been shown to induce improvements in body composition, supporting the utility of aquatic exercise when mechanical limitations restrict conventional exercise participation (del Castillo et al., 2021). Likewise, health-related physical fitness remains consistently associated with body composition and physical activity levels in adult populations, further highlighting the relevance of physical fitness in cardiometabolic management (Enriquez-Del Castillo et al., 2021).

In the specific context of T2DM, a previous meta-analysis of aquatic exercise reported significant reductions in HbA1c, although it identified limitations related to sample size and methodological heterogeneity among the included studies (Rees et al., 2017). More recent clinical trials have investigated both aerobic and combined aquatic exercise programs, reporting improvements in glycemic control, blood pressure, and other physiological markers (Connors et al., 2019; Delevatti et al., 2022; Delevatti et al., 2024; Delevatti et al., 2016). Similarly, recent reviews of exercise and metabolic syndrome have confirmed the effectiveness of structured training in improving cardiometabolic indicators, supporting the role of exercise as a comprehensive strategy for populations with metabolic disorders (Syeda et al., 2023). These findings suggest that the aquatic environment may represent a viable alternative when land-based exercise is less well tolerated.

Despite the growing body of evidence on exercise in T2DM, most systematic reviews have focused on interventions conducted in land-based settings (Llopiz & García-Galbis, 2015; Yuing et al., 2019; Parada Flores et al., 2023; Selçuk, 2019). The specific integration of studies evaluating aquatic exercise programs remains limited, making it difficult to establish conclusions regarding their magnitude of effect and clinical applicability.

Therefore, the objective of the present systematic review was to analyze the acute responses and chronic effects of aquatic exercise programs in adults with T2DM, considering HbA1c and fasting blood glucose as the primary outcomes.

Methods

Study Design and Search Strategy

A systematic review was conducted in accordance with the guidelines of the PRISMA 2021 statement (Page et al., 2021). The literature search was conducted between February 1 and 28, 2026, using the PubMed, Web of Science, Scopus, and Cochrane Library databases. No publication date restrictions were applied.

The search strategy was structured according to the PICO framework (Population, Intervention, Comparison, and Outcome). MeSH terms and keywords related to type 2 diabetes mellitus, aquatic exercise, and glycemic control were combined using Boolean operators (AND, OR, NOT). The search equations were adapted to the specific syntax of each database with the support of the Polyglot Search Translator (Clark et al., 2020).

In addition, a manual search of cross-references was performed, and related literature was explored using Connected Papers to identify potentially eligible studies. Publications in English and Spanish were considered eligible.

Eligibility Criteria

Studies meeting the following criteria were included:

- Clinical trials;
- Adult population (≥ 18 years) with a diagnosis of type 2 diabetes mellitus;
- Interventions based on structured physical exercise programs conducted in an aquatic environment;
- Reporting at least one of the primary outcomes: glycated hemoglobin (HbA1c) and/or fasting blood glucose;
- Availability of quantitative data for the outcomes of interest.

Reviews, meta-analyses, observational studies, editorials, brief communications, conference abstracts without full-text availability, interventions not conducted in an aquatic environment, and studies involving pediatric populations or other types of diabetes were excluded.

Selection Process

The identified records were managed using Rayyan software. Two independent reviewers (TSBM and LAEC) conducted the search, title and abstract screening, and full-text assessment. Disagreements were resolved by consensus.

Data Extraction

The following data were extracted from each included study: sample size, sex distribution, mean age and standard deviation, study design characteristics, type of intervention, exercise intensity, weekly frequency, session duration, total number of sessions, and outcomes related to HbA1c and fasting blood glucose. Secondary outcomes reported by the authors, such as hemodynamic and body composition variables, were also recorded.

Risk of Bias Assessment

The risk of bias in the included trials was assessed using the ROBINS tool (Sterne et al., 2016). The domains related to the randomization process, deviations from the intended intervention, missing outcome data, outcome measurement, and selection of the reported result were evaluated. The assessment was performed independently by both reviewers, and any discrepancies were resolved by consensus.

Data Synthesis

Due to heterogeneity in intervention duration, number of sessions, exercise intensity, and outcome measures, a meta-analysis was not performed. A narrative synthesis was conducted, focusing on the effects on HbA1c and fasting blood glucose. When available, absolute changes and the statistical significance reported by the authors were recorded.

Selection Flow

The initial search identified 100 records (PubMed, n = 5; Scopus, n = 93; Web of Science, n = 2; Cochrane Library, n = 0). After removing three duplicates, 97 records were screened by title and abstract, of which 94 were excluded for not meeting the inclusion criteria. Three studies were assessed in full text, and one was excluded because it did not meet the established methodological criteria. The complementary search identified three additional studies. Finally, five studies were included in the qualitative synthesis (Figure 1).

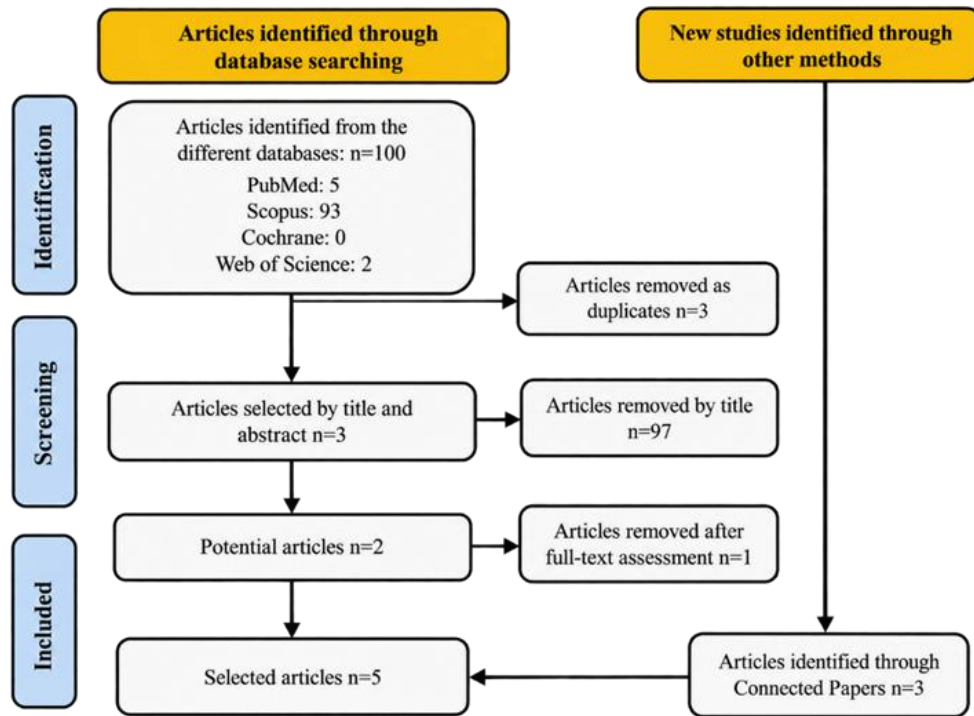


Figure 1: Selection flowchart

Results

Characteristics of the Included Studies

Five clinical trials published between 2014 and 2024 were included, comprising a total of 151 adult participants diagnosed with type 2 diabetes mellitus (T2DM). Of these, 85 were women and 66 were men. Four studies had a predominantly female sample, whereas one study reported an equal distribution between sexes.

The mean age ranged from 53 to 61 years. The interventions were predominantly conducted three times per week, while one study scheduled sessions at 48-hour intervals. Exercise intensity ranged from moderate to moderate-to-vigorous.

Session duration ranged from 30 to 60 minutes. Three studies combined aquatic aerobic exercise with resistance training, whereas two implemented aquatic aerobic exercise exclusively. The total number of sessions ranged from 5 to 45. The characteristics of the included studies are presented in Table 1.

Table 1: Characteristics of the included studies

Authors and year	Sample	Age (years)	Frequency	Intensity	Time (minutes)	Type	Duration (sessions)	Results
Conners et al., 2019	n = 7 Women = 5 Men = 2	53.3 ± 7.7	3 times per week	Moderate	30–60	Aquatic aerobic exercise and muscle resistance	24	↓ HbA1c* ↓ Body mass* ↓ Waist circumference* ↓ Body fat percentage*
Delevatti et al., 2022	n = 57 Women = 29 Men = 28	AEG: 57.5 ± 7.4 CTG: 60.9 ± 7.4 CG: 58.6 ± 9.7 CG: 64.20 ± 12.08 EG: 62.22 ± 11.44	3 times per week	Moderate to vigorous	50	Aquatic aerobic exercise and muscle resistance	45	↓ HbA1c* ↓ Diastolic blood pressure* ↓ Renin concentration* ↔ Fasting insulin
Cândido et al., 2022	n = 40 Women = 25 Men = 15	12.08 EG: 62.22 ± 11.44	3 times per week	Moderate	60	Aquatic aerobic exercise and muscle resistance	15	↔ Capillary glucose ↓ Electroencephalographic activity*
Delevatti et al., 2024a	n = 12 Women = 6 Men = 6	53.2 ± 8.9	Every 48 hours	Moderate to vigorous	45	Aquatic aerobic exercise	5	↓ Glucose ↓ Plasma renin
Delevatti et al., 2024b	n = 35 Women = 20 Men = 15	55.3 ± 7.7	3 times per week	Moderate to vigorous	45	Aquatic aerobic exercise	36	↓ Glucose ↓ HbA1c* ↓ Total cholesterol*

(↓ Reduction, CG: Control group, EG: Experimental group, %: Percentage, AG: Aerobic group, CG: Combined group, *: Significant change, ↔: No change, HbA1c: Glycated hemoglobin)

Effects on HbA1c and Glucose

Three studies reported significant reductions in HbA1c following the intervention. The decreases were observed primarily in protocols involving a greater number of sessions (≥ 24). One study reported no significant changes in fasting insulin levels.

Significant reductions in glucose levels were observed in three studies. In one of them, the reduction was recorded following a brief five-session protocol. Another study found no significant changes in capillary blood glucose after 15 sessions.

Secondary Outcomes

In addition to changes in glycemic parameters, some studies reported significant reductions in body mass, waist circumference, body fat percentage, diastolic blood pressure, total cholesterol, and plasma renin concentration. One study reported changes in electroencephalographic activity without concomitant changes in capillary blood glucose.

Risk of Bias Assessment

The risk-of-bias assessment using the ROBINS tool indicated that most studies had a low risk of bias in the domain related to the randomization process. However, some concerns were identified regarding missing outcome data and selective reporting in certain studies. No trial was globally classified as having a high risk of bias. Domain-specific judgments are presented in Figure 2.

Study	D1	D2	D3	D4	D5	D6	D7	Overall
Connors et al., 2014								
Delevatti et al., 2022								
Cândido et al., 2022								
Delevatti et al., 2024a								
Delevatti et al., 2024b								

Domains:

D1: Bias arising from the randomization process
D2: Bias due to deviations from the intended interventions
D3: Bias due to classification of interventions
D4: Bias due to missing outcome data
D5: Bias in the measurement of outcomes
D6: Bias due to selection of the reported result
D7: Bias due to selective reporting

Judgment:

High risk
 Some concerns
 Low risk

Figure 2: Risk-of-bias domains

Discussion

The present systematic review included five clinical trials evaluating aquatic exercise programs in adults with type 2 diabetes mellitus (T2DM). The results presented in Table 1 show that interventions involving a greater number of sessions (≥ 24) were associated with significant reductions in glycated hemoglobin (Connors et al., 2019; Delevatti et al., 2022; Delevatti et al., 2016), whereas changes in fasting blood glucose were less consistent, with reductions reported in three studies (Connors et al., 2019; Delevatti et al., 2024; Delevatti et al., 2016). The observed variability suggests that the cumulative duration of the program and the prescribed exercise intensity may influence the magnitude of the metabolic response.

The established literature on exercise in T2DM, predominantly conducted in land-based settings, has demonstrated clinically relevant

reductions in HbA1c through aerobic and combined training (Umpierre et al., 2011; Kumar et al., 2019; Boulé et al., 2001). Recent meta-analyses have confirmed that reductions in HbA1c are influenced by weekly frequency and total training volume (Kumar et al., 2019; Boulé et al., 2001). The aquatic interventions analyzed in this review used intensity and frequency parameters comparable to those described in land-based studies, supporting the physiological plausibility of the observed adaptations.

A previous meta-analysis specifically examining aquatic exercise in T2DM reported a significant reduction in HbA1c, although it highlighted methodological heterogeneity and the small sample sizes of the available trials (Rees et al., 2017). The more recent clinical trials included in the present review confirm this trend, particularly in longer-duration protocols (Connors et al., 2019; Delevatti et al., 2022; Delevatti et al., 2016). The evidence suggests that the aquatic environment does not limit the metabolic response when the training stimulus reaches moderate-to-vigorous intensities.

From a biomechanical perspective, the aquatic environment reduces joint loading through the effect of buoyancy and modifies the hemodynamic response through hydrostatic pressure (Becker, 2009; Tomescu et al., 2025). Experimental studies have demonstrated reduced joint forces at the hip and knee during activities performed in immersion (Pöyhönen et al., 1999), which may facilitate participation among individuals with obesity or osteoarticular pain, conditions commonly observed in T2DM. Research in adults with obesity has demonstrated improvements in body composition following moderate-intensity aquatic and land-based interventions (del Castillo et al., 2021), and an association between physical fitness and body composition has been reported in adult populations (Enriquez-Del Castillo et al., 2021). These findings provide clinical support for the secondary changes observed in some of the included studies, such as reductions in body mass, waist circumference, and body fat percentage (Connors et al., 2019).

Regarding hemodynamic and hormonal variables, some trials reported reductions in diastolic blood pressure and plasma renin concentration (Delevatti et al., 2022; Delevatti et al., 2024). These findings are consistent with the systemic effects of regular exercise described in international consensus statements and reviews addressing exercise and T2DM (Boulé et al., 2001). However, the diversity of intervention protocols prevents the establishment of a precise dose-response relationship.

One of the shorter-duration studies showed an acute reduction in glucose following five sessions (Delevatti et al., 2024), whereas another study found no significant changes after 15 sessions (Delevatti et al., 2024). These differences may be attributable to sample size, interindividual variability, or the method used to assess glucose levels. The available

evidence does not allow aquatic exercise to be considered superior to land-based exercise; rather, it suggests that aquatic exercise may represent an equivalent modality when appropriate exercise prescription principles are applied.

Systematic reviews focusing on land-based exercise have established the role of structured training in reducing HbA1c (Llopiz & García-Galbis, 2015; Yuing et al., 2019; Parada Flores et al., 2023). However, the evidence specifically synthesizing aquatic interventions remains limited. The number of controlled trials is small, and substantial heterogeneity exists in exercise intensity, duration, and study design. Direct comparisons between modalities require adequately powered studies with parallel-group designs.

Conclusions

Aquatic exercise programs are associated with improvements in glycemic control in adults with type 2 diabetes mellitus, particularly when implemented at moderate-to-vigorous intensity and for a sufficient duration to induce sustained metabolic adaptations. The reductions in glycated hemoglobin observed in interventions involving a greater number of sessions support their potential clinical utility as an adjunct to pharmacological treatment.

The aquatic environment offers biomechanical advantages that may facilitate adherence among individuals with osteoarticular limitations or overweight, thereby expanding therapeutic options for this population. However, the available evidence remains limited in terms of the number of studies and presents considerable methodological heterogeneity, preventing definitive recommendations regarding the optimal exercise dose, duration, or superiority over land-based exercise.

Clinical trials with larger sample sizes, standardized protocols, and long-term follow-up are needed to more accurately estimate the magnitude of the effects of aquatic exercise on glycemic and cardiometabolic outcomes in individuals with T2DM.

Limitations

The main limitation of this review is the small number of available studies and the heterogeneity of the intervention protocols. Differences in intervention duration, total number of sessions, and exercise intensity precluded the performance of a quantitative meta-analysis. In addition, although all studies were clinical trials, some raised concerns in specific risk-of-bias domains. Language restrictions and the absence of prior protocol registration should also be considered when interpreting the findings.

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