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Swimming and Aquatic Exercise for Lipid Profile Management: A Narrative Review of Physiological Responses and Implications for Biology Education

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ABSTRACT

Swimming and aquatic exercise have been studied for their effects on lipid profiles, but findings remain inconsistent. This narrative review synthesises two intervention studies and one published meta-analysis, focusing on total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and triglycerides (TG). A 12-month swimming program showed lower total cholesterol and LDL-C than walking, whereas a 28-week aquatic exercise program found no significant lipid changes. Published swimming-subgroup confidence intervals crossed zero for all four outcomes. These contrasting findings provide a practical context for biology education, particularly teaching lipid metabolism, physiological adaptation, and critical interpretation of research evidence using exercise-based examples of biological variability and uncertainty. Future studies should compare freestyle and breaststroke under standardised conditions. Educational applications are proposed conceptually and have not been evaluated empirically.

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1. INTRODUCTION

Physical activity plays an important role in maintaining metabolic health, particularly through its potential effects on blood lipid concentrations. Lipid profiles commonly include total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and triglycerides (TG). Swimming and aquatic exercise have been investigated as interventions for modifying these parameters. However, their effects remain inconsistent across populations and exercise programs, indicating the need for careful interpretation of existing findings [1-3].

Swimming involves coordinated whole-body movements against water resistance, whereas aquatic exercise includes additional activities such as water walking, aquatic aerobics, and combined training. These activities differ in movement patterns and physical demands. A comparative study involving 116 sedentary women aged 50-70 years demonstrated significantly lower TC and LDL-C concentrations following a 12-month swimming intervention compared with walking [1]. In contrast, a 28-week aquatic exercise intervention involving continuous aerobic, interval aerobic, and combined training programs showed no significant changes in conventional lipid parameters [2]. Lipid responses may vary depending on exercise characteristics, intervention protocols, and participant populations [1, 2]. A meta-analysis of regular aquatic endurance exercise reported favorable changes in several lipid parameters in its overall analysis [3]. However, 95% confidence intervals crossed zero for TC, HDL-C, LDL-C, and TG, indicating statistically inconclusive effects [3]. Improvements associated with aquatic exercise cannot necessarily be generalized to swimming alone. Differences in exercise duration, intensity, participant characteristics, and comparison conditions may contribute to variations in lipid responses, although their individual contributions remain uncertain [1-3]. These findings also have implications for biology education. Swimming-related lipid responses can provide contextual examples for teaching lipid metabolism, human physiology, homeostasis, and physiological adaptation. Furthermore, comparing intervention findings can introduce students to experimental design, biological variability, and statistical interpretation. Differences between freestyle and breaststroke may also provide a context for discussing human movement and energy metabolism. However, the reviewed studies do not establish differences in lipid responses between these strokes or demonstrate the effectiveness of their use in biology education.

Exercise training can improve blood lipid profiles, although the magnitude of these improvements varies across exercise modalities and participant populations [4]. Dietary interventions and combined exercise–diet programmes may also influence lipid responses, highlighting the importance of considering nutritional factors when evaluating exercise-related metabolic changes [5]. Water-based aerobic and resistance training have shown favourable effects on lipid profiles among women with dyslipidemia, supporting the potential benefits of aquatic exercise [6]. From an educational perspective, interpreting scientific graphs and experimental data is important for developing students' understanding of biological concepts and scientific evidence [7]. Activities involving data presentation and interpretation are also relevant to developing scientific reasoning in science education [8]. Contextual inquiry-based learning and dynamic visualization tools have been investigated for supporting students' conceptual understanding and engagement in biology education [9, 10].

Technology-based instructional videos have also demonstrated potential for improving cognitive and physical performance in physical education [11].

This study aims to review the effects of swimming and aquatic exercise on conventional lipid profiles and identify their implications for swimming stroke research and biology education. The review focuses on TC, HDL-C, LDL-C, and TG by synthesizing findings from controlled intervention studies and a published meta-analysis. Particular attention is given to differences in exercise protocols, reported physiological outcomes, and their potential application to teaching biological concepts and scientific data interpretation.

2. METHODS

This study employed a focused narrative review to examine the effects of swimming and aquatic exercise on conventional lipid profiles and explore their implications for biology education. Three publications were included as the principal evidence base: two controlled intervention studies [1,2] and one published meta-analysis [3]. The literature was selected from an existing collection and verified through targeted searches of PubMed, publisher websites, and accessible reports updated on 11 October 2026. Selection focused on studies reporting swimming or aquatic exercise interventions with TC, HDL-C, LDL-C, or TG outcomes. The review did not involve an exhaustive systematic search or a registered review protocol.

Data extracted from the selected publications included study design, participant characteristics, sample size, intervention duration, exercise protocol, comparison group, lipid outcomes, and reported statistical findings. The findings were compared narratively to identify similarities, differences, and limitations across interventions. Experimental findings were distinguished from previously published pooled estimates. Statistical non-significance was not interpreted as evidence of equivalence. Educational implications were developed conceptually by relating the reviewed findings to lipid metabolism, physiological adaptation, and scientific data interpretation. No educational intervention or learning outcome assessment was conducted.

Lipid concentrations were standardized to mmol/L using conversion factors of 38.7 for cholesterol parameters and 88.7 for triglycerides [3]. The conversions were calculated using $\text{Cholesterol (mmol/L)} = \frac{\text{Cholesterol (mg/dL)}}{38.7}$ and $\text{Triglycerides (mmol/L)} = \frac{\text{Triglycerides (mg/dL)}}{88.7}$.

A forest plot was reconstructed from the published swimming-subgroup estimates and 95% confidence intervals reported by Igarashi and Nogami [3]. The plot illustrates the direction and uncertainty of lipid responses without performing a new meta-analysis. No additional pooled effects, study weights, or heterogeneity statistics were calculated. Confidence intervals crossing zero were considered statistically inconclusive, and the four lipid outcomes were presented separately.

3. RESULTS AND DISCUSSION

3.1. Characteristics of Swimming and Aquatic Exercise Studies

The reviewed publications examined swimming and aquatic exercise interventions involving different participant populations, exercise protocols, and comparison conditions. The intervention studies involved sedentary older women and community-dwelling older adults, whereas the published meta-analysis combined evidence from randomized controlled trials investigating aquatic endurance exercise [1-3]. These differences are important because

participant characteristics and intervention designs may influence the interpretation of lipid responses. **Table 1** summarizes the main characteristics of the reviewed publications. The reviewed studies differed in intervention duration, exercise characteristics, and control conditions. The swimming intervention lasted 12 months, whereas the aquatic exercise programs lasted 28 weeks [1, 2]. Swimming was compared with walking in one study, while the other employed a usual-routine control group. The reported findings should be interpreted according to their respective experimental designs rather than directly compared as equivalent interventions.

Table 1. Characteristics of the reviewed swimming and aquatic exercise studies.

PARTICIPANTS	INTERVENTION	MAIN FINDINGS	REF.
116 women aged 50-70 years	Swimming versus walking, 12 months	Significantly lower TC and LDL-C with swimming	[1]
152 randomized older adults; 102 completed	Three aquatic exercise programs, 28 weeks	No significant conventional lipid changes	[2]
Meta-analysis; swimming subgroup: 3 comparisons, n = 125 per outcome	Swimming versus non-exercising controls	Confidence intervals crossed zero for all four lipid outcomes	[3]

3.2. Effects of Swimming and Aquatic Exercise on Lipid Profiles

Swimming and aquatic exercise demonstrated different effects on conventional lipid parameters across the reviewed intervention studies. A 12-month swimming intervention produced significantly lower TC and LDL-C compared with walking, with reported differences of −0.30 and −0.20 mmol/L, respectively [1]. A 28-week aquatic exercise intervention did not demonstrate statistically significant changes in TC, HDL-C, LDL-C, or TG [2].

Table 2 presents the principal lipid findings. Swimming may provide favorable changes in selected lipid parameters under particular intervention conditions. The favorable results from the swimming-versus-walking trial cannot be generalized to all aquatic exercise programs. Differences in baseline lipid concentrations, intervention duration, exercise intensity, and participant characteristics may contribute to variation in lipid responses, although the available studies do not establish the independent effects of these factors [1, 2].

Table 2. Reported effects of swimming and aquatic exercise on lipid profiles.

LIPID PARAMETER	REPORTED RESULT	STATISTICAL INTERPRETATION	REF.
TC	−0.30 mmol/L	p = 0.040	[1]
LDL-C	−0.20 mmol/L	p = 0.049	[1]
TC	No significant change	Not statistically significant	[2]
HDL-C	No significant change	Not statistically significant	[2]
LDL-C	No significant change	Not statistically significant	[2]
TG	No significant change	Not statistically significant	[2]

3.3. Quantitative Interpretation of Swimming-Related Lipid Changes

The published swimming-subgroup analysis provided additional information regarding the direction and uncertainty of lipid responses. The reported estimates indicated a positive change in HDL-C and negative changes in LDL-C, TC, and TG. All corresponding 95% confidence intervals crossed zero, indicating that the swimming-subgroup effects were statistically inconclusive [3]. **Table 3** presents the published estimates after conversion to mmol/L.

Table 3. Published swimming-subgroup lipid changes and 95% confidence intervals [3].

LIPID PARAMETER	ESTIMATE (mg/dL)	ESTIMATE (mmol/L)
HDL-C	+5.3 [−1.1, +11.7]	+0.137 [−0.028, +0.302]
LDL-C	−0.6 [−14.4, +13.2]	−0.016 [−0.372, +0.341]
TC	−4.0 [−17.7, +9.8]	−0.103 [−0.457, +0.253]
TG	−24.2 [−48.8, +0.4]	−0.273 [−0.550, +0.005]

Figure 1 illustrates the published swimming-subgroup estimates and their corresponding confidence intervals. Although HDL-C demonstrated a positive numerical estimate and the other lipid parameters showed negative estimates, the intervals crossed the zero-effect line. The TG estimate approached statistical significance but remained inconclusive because its upper confidence limit was positive. Therefore, these results should not be interpreted as definitive evidence of lipid improvement following swimming interventions [3]. Forest plot of published swimming-subgroup pooled net changes and 95% confidence intervals for HDL-C, LDL-C, TC, and TG. Estimates were reproduced from the supplementary analysis of a previously published meta-analysis and converted into mmol/L. The vertical reference line indicates zero change. All confidence intervals cross zero, indicating statistically inconclusive swimming-subgroup effects [3].

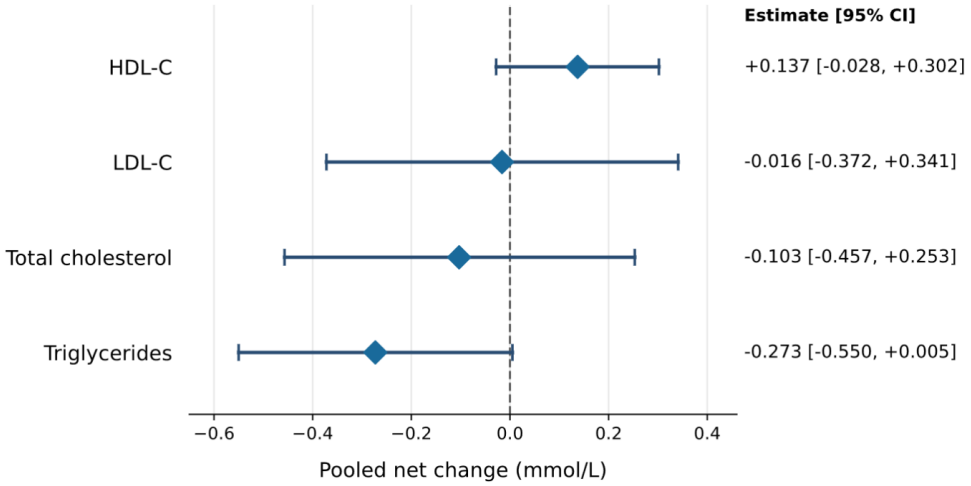


Figure 1. Forest plot of swimming-subgroup lipid responses.

The comparison of these results highlights the importance of distinguishing numerical trends from statistically supported physiological responses. A favourable direction of change does not necessarily indicate a significant intervention effect. Furthermore, the published meta-analysis represents secondary evidence and should not be considered an additional independent intervention trial. Consequently, the present review uses these estimates to illustrate existing evidence rather than to perform a new meta-analysis.

3.4. Influence of Exercise Characteristics on Lipid Responses

Exercise duration, frequency, intensity, and participant characteristics are important considerations when interpreting changes in lipid profiles. Exercise training can improve blood lipid concentrations, although responses vary across exercise modalities and participant populations [4]. Dietary interventions and combined exercise–diet programmes have shown different effects on lipid profiles, highlighting the importance of considering nutritional factors when evaluating exercise-related metabolic responses [5]. However, the

available findings cannot establish whether longer interventions consistently produce greater lipid improvements. Differences in comparison groups further limit direct interpretation across studies [1, 2]. Dietary assessment and nutritional management are also important considerations when examining metabolic health. Previous literature has emphasised the importance of nutritional assessment, intervention planning, and monitoring in managing nutrition-related metabolic conditions [12]. Therefore, future swimming interventions should consider participants' dietary habits when evaluating changes in lipid profiles.

Water-based aerobic and resistance training have demonstrated favourable lipid responses among older women with dyslipidemia, suggesting that aquatic exercise may provide metabolic benefits under specific intervention conditions [6]. Swimming stroke selection represents another relevant consideration because freestyle and breaststroke involve different movement patterns, body positions, and coordination requirements. However, these differences do not establish that either stroke produces superior lipid improvements. These differences may influence exercise demands, but their effects on conventional lipid concentrations remain uncertain. No direct comparison of freestyle and breaststroke lipid responses was established within the selected evidence. Future studies should therefore standardize exercise duration, intensity, participant characteristics, and biochemical measurement procedures before evaluating potential differences between swimming strokes.

3.5. Implications for Biology Education

he reviewed findings provide a potential context for teaching biological concepts related to lipid metabolism, human physiology, and physiological adaptation. Contextualised inquiry-based learning has been shown to support students' conceptual understanding in biology, suggesting that physiological responses to swimming could provide relevant real-world learning materials [9]. Furthermore, dynamic visualisation tools have been reported to improve students' motivation and engagement in biology education, supporting the proposed use of graphical lipid-profile data as instructional resources [10]. Changes in TC, HDL-C, LDL-C, and TG can be used as examples to explain how biological indicators are measured and interpreted in exercise research. Interpretation and evaluation are important competencies in biology education, particularly for developing students' abilities to analyse biological data and understand scientific evidence [7]. Swimming and aquatic exercise may also serve as familiar activities for connecting theoretical knowledge of metabolism with practical examples of human physiological responses. Previous research on nutrition education has reported improvements in students' understanding of balanced dietary habits and drinking water quality [13]. Integrating nutrition education with swimming-related physiological data could therefore provide a broader learning context for understanding the relationships among diet, metabolism, and physical activity.

The contrasting findings from swimming and aquatic exercise interventions can support proposed learning activities involving scientific data interpretation. For example, students could compare experimental groups, identify independent and dependent variables, calculate changes in lipid concentrations, and interpret statistical significance. Learning activities involving data presentation and interpretation have been associated with students' scientific reasoning, supporting the relevance of evidence-based analytical activities in science education [8]. The confidence intervals presented in **Table 3** and **Figure 1** could also be used to explain uncertainty in biological measurements. Such activities are conceptually relevant

to scientific reasoning and data literacy, although their effectiveness in improving learning outcomes was not evaluated in the reviewed studies.

The comparison between freestyle and breaststroke may provide an additional educational context for discussing muscular coordination, movement mechanics, energy utilisation, and experimental design. Technology-based instructional videos have also demonstrated potential for improving students' cognitive understanding and physical performance in physical education, suggesting that visual learning materials could complement the teaching of swimming techniques and related physiological concepts [11]. Students could formulate hypotheses about physiological differences between swimming strokes and propose appropriate measurement procedures. These educational applications are proposed as possibilities for biology teaching rather than established instructional outcomes.

3.6. Limitations and Future Research Directions

This review was limited to two intervention studies and one published meta-analysis. The selected publications differed in participant characteristics, exercise protocols, and comparison conditions, restricting direct comparisons and generalization. Furthermore, the forest plot reproduced previously published subgroup estimates without conducting a new meta-analysis. The absence of a comprehensive literature search and formal risk-of-bias assessment also limits the strength of the conclusions. Future investigations should compare freestyle and breaststroke using controlled exercise protocols and consistent lipid measurement procedures. Studies should account for baseline lipid concentrations, dietary intake, medication use, exercise intensity, and adherence. future educational research should investigate whether integrating exercise-related biochemical data and graphical representations into biology instruction improves students' understanding of lipid metabolism, physiological adaptation, and scientific data interpretation. Such investigations could evaluate students' conceptual understanding and ability to interpret experimental findings, providing empirical evidence for the proposed educational applications.

4. CONCLUSION

Swimming and aquatic exercise demonstrated inconsistent effects on conventional lipid profiles. A 12-month swimming intervention reported lower total cholesterol and LDL-C than walking, whereas a 28-week aquatic exercise program showed no significant lipid changes. Published swimming-subgroup estimates were statistically inconclusive for all four lipid outcomes. These findings show the importance of exercise protocols, participant characteristics, and statistical interpretation. The reviewed evidence does not establish superior lipid benefits from freestyle or breaststroke. For biology education, the findings offer potential examples for teaching lipid metabolism and scientific data interpretation. Further controlled physiological studies and educational evaluations are needed to examine these applications.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper is free from plagiarism.

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