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Changes in growth hormone and insulin-like growth factor (IGF-1 and GH) after a period of endurance swimming training in children

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Original Research
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Abstract

Purpose: Growth hormone (GH) and insulin-like growth factor-1 (IGF-1) are critical for somatic development, linear bone growth, and metabolic homeostasis in children. Physical activity, especially endurance training, plays a significant role in modulating these hormones. Therefore, the aim of this study was to investigate the effects of an 8-week endurance swimming training program on GH and IGF-1 levels in prepubertal children. **Method:** The study involved 30 healthy children aged 9–11 years, randomly assigned to either a swimming group (15 children) or a control group (15 children). The swimming group participated in a structured 8-week training program, three times per week, with each session lasting 60 minutes. GH and IGF-1 levels were measured before and 48 hours after the intervention using enzyme-linked immunosorbent assay (ELISA). Statistical analysis included two-way repeated-measures ANOVA to compare the effects of the training on hormone levels between the groups, with p-values set at 0.05. **Results:** The results revealed a significant increase in GH for the swimming group (from 17.4±0.9 to 22.9±1.1 ng/mL, $p<0.001$) compared to the control group (from 17.5±1.0 to 17.7±1.1 ng/mL, $p=0.384$). For IGF-1, the swimming group also showed a significant rise (from 212.3 ± 24.5 to 232.8±26.1 ng/mL, $p=0.018$), while the control group showed no significant change ($p=0.413$). **Conclusion:** The findings suggest that moderate-intensity endurance swimming can effectively stimulate the GH and IGF-1 axis in prepubertal children, independent of major anthropometric changes. These results support the inclusion of swimming as a safe and effective form of exercise to promote growth-related hormonal health in children.

Keywords: Growth hormone, insulin-like growth factor I, swimming, endurance training.

Introduction

Growth and maturation during childhood are critically dependent on the coordinated regulation of the growth hormone (GH) and insulin-like growth factor-1 (IGF-1) axis. This endocrine system plays a central role in somatic development, linear bone growth, protein synthesis, and metabolic homeostasis (Alipio & Tourinho Filho, 2025; Nemet et al., 2005). GH, secreted in a pulsatile manner by the anterior pituitary, stimulates hepatic and peripheral production of IGF-1, which mediates many of GH's anabolic actions through endocrine, paracrine, and autocrine mechanisms (Birzniece & Ho, 2019). Because components of the GH–IGF-1 axis are highly sensitive to physiological and environmental stimuli, physical activity has been recognized as one of the most potent non-pharmacological modulators of growth-related hormones in children (Alipio & Tourinho Filho, 2025; Scheett et al., 2002).

Endurance training represents a particularly relevant stimulus, as it involves prolonged activation of large muscle groups, increased metabolic demand, lactate accumulation, alterations in thermoregulation, and sustained cardiovascular stress (Weltman et al., 1992; Scheett et al., 2002). These factors can acutely enhance GH secretion and, over time, may influence circulating IGF-1 levels (Eliakim & Nemet, 2007; Birzniece & Ho, 2019). However, current evidence in pediatric populations is inconsistent. Some endurance-based interventions in children and adolescents have reported significant increases in GH or IGF-1 (Mejri et al., 2005; Jansson et al., 2022), whereas others have shown no change or even decreases in these hormones (Scheett et al., 2002; Jansson et al., 2022). Differences in training modality, intensity, duration, and total load, as well as heterogeneity in age, sex, pubertal status, and nutritional state, appear to contribute to this variability in endocrine responses (Jansson et al., 2022; Alipio & Tourinho Filho, 2025).

Swimming is a common and attractive form of endurance training for children, and its physiological profile is distinct from land-based exercise. The aquatic environment reduces mechanical loading on

joints, alters hydrostatic pressure and venous return, and facilitates heat dissipation (Alipio & Tourinho Filho, 2025). At the same time, swimming can impose substantial metabolic and cardiorespiratory demands, especially when training involves continuous or interval work engaging large muscle groups of both upper and lower limbs (Nemet et al., 2005). These characteristics make swimming a suitable model for examining GH and IGF-1 responses to endurance exercise in children. Experimental data from prepubertal boys indicate that several weeks of moderate-intensity swimming can significantly increase circulating GH compared with non-training controls, suggesting that structured endurance swimming is capable of effectively stimulating the somatotropic axis during childhood (Birzniece & Ho, 2019; Nemet et al., 2005). Nevertheless, not all endurance-type interventions in youth produce comparable hormonal adaptations. Studies involving intensive or high-volume aerobic training have reported transient reductions in IGF-1, often accompanied by elevations in pro-inflammatory cytokines such as interleukin-6, tumor necrosis factor-alpha, and interleukin-1 beta (Nemet et al., 2005; Scheett et al., 2002). These cytokines can suppress IGF-1 bioactivity by increasing inhibitory IGF-binding proteins, thereby promoting a predominantly catabolic internal milieu in the early phase of training (Birzniece & Ho, 2019). Some authors have proposed a biphasic model in which an initial catabolic phase, characterized by reduced IGF-1 and elevated cytokines, is followed by an anabolic phase after several weeks of continued training, when inflammatory markers decline and IGF-1 levels rebound or even surpass baseline values (Eliakim & Nemet, 2007; Jansson et al., 2022). This model underscores the importance of training duration and periodization when interpreting endocrine responses to endurance exercise (Birzniece & Ho, 2019).

Developmental stage is another key determinant of GH and IGF-1 kinetics. GH secretion in children is pulsatile and increases progressively with age, reaching its highest levels during puberty (Jansson et al., 2022; Eliakim & Nemet, 2007). Prepubertal children show different endocrine responses to exercise than adolescents, in part

due to lower baseline GH amplitude, differences in somatostatin and growth hormone-releasing hormone tone, and the absence of sex steroid potentiation of the GH–IGF-1 axis (Birzniece & Ho, 2019). Consequently, identical endurance protocols may lead to divergent hormonal adaptations depending on maturational status, making focused research in prepubertal cohorts particularly important for understanding exercise–growth interactions (Scheett et al., 2002).

In addition to direct hormonal effects, endurance training may indirectly modulate the GH–IGF-1 axis through changes in body composition and fitness. Regular aerobic exercise and swimming in children have been associated with reductions in adiposity and increases in lean body mass, adaptations that favor a more anabolic environment (Eliakim & Nemet, 2007). Excess adipose tissue, conversely, is linked with blunted GH secretion and reduced IGF-1 bioavailability (Birzniece & Ho, 2019). Thus, improvements in metabolic health and cardiorespiratory fitness induced by endurance training may contribute to more favorable GH and IGF-1 profiles over time (Alipio & Tourinho Filho, 2025).

Despite the expanding literature, the magnitude, direction, and consistency of GH and IGF-1 responses to endurance training in children remain unclear, particularly for swimming-based programs in prepubertal populations. Given the sensitivity of growth processes to both hormonal and mechanical stimuli during childhood, clarifying these relationships has important implications for designing safe and effective exercise prescriptions (Jansson et al., 2022; Birzniece & Ho, 2019). Therefore, the aim of the present study is to investigate changes in GH and IGF-1 following an endurance swimming training program in children, providing new evidence on how structured aerobic exercise may influence key anabolic hormones during a critical period of growth and development (Eliakim & Nemet, 2007).

Methods

Study design and participants

This study included healthy prepubertal children aged 9–11 years who were free from endocrine, metabolic, cardiovascular, or chronic diseases and had not been engaged in any structured exercise training for at least six months prior to enrollment. Maturation status was verified using self-assessed Tanner staging under parental guidance, and only children classified as Tanner stage I were included to ensure a homogeneous prepubertal sample. Exclusion criteria comprised any history of musculoskeletal injury, use of medications known to affect hormonal function, poor swimming ability incompatible with the training protocol, or contraindications to moderate-intensity exercise. Anthropometric characteristics including height, body mass, and body mass index (BMI) were measured according to standardized pediatric procedures. After baseline assessments, participants were randomly allocated to either an endurance swimming training group or a non-exercising control group. The study protocol was approved by an institutional ethics committee, and written informed consent was obtained from parents or legal guardians, along with assent from all participating children.

Swimming Training Protocol

The intervention consisted of an 8-week endurance swimming training program designed in accordance with protocols previously used to examine GH and IGF-1 responses to aquatic exercise in children. Training sessions were held three times per week on non-consecutive days, each lasting 60 minutes, and were supervised by certified swimming coaches and an exercise physiologist to ensure safety and adherence to the prescribed intensity. Each session began with approximately 10 minutes of low-intensity warm-up in and out of the water, followed by 40 minutes of continuous or interval-based swimming using predominantly freestyle and backstroke to engage

large muscle groups of both the upper and lower body, and concluded with 10 minutes of low-intensity swimming and stretching as a cool-down. Exercise intensity was maintained at 45–65 percent of age-predicted maximal heart rate (HRmax), monitored throughout the main set using waterproof heart-rate monitors. This moderate-intensity range was chosen to provide sufficient metabolic and cardiovascular stress to stimulate the somatotropic axis while remaining appropriate and safe for prepubertal children. Participants in the control group were instructed to maintain their usual daily activities and not to engage in any new structured physical training during the 8-week period.

Blood Sampling Procedures

Venous blood samples were collected at two time points: at baseline, prior to the start of the training program, and 48 hours after the final training session to minimize the influence of acute exercise on circulating hormone levels. All samples were drawn in the morning between 08:00 and 09:00 after an overnight fast of at least 10 hours, with participants instructed to avoid vigorous physical activity for 24 hours before each sampling. Blood was obtained from an antecubital vein while the child was seated and at rest for at least 10 minutes, using standard aseptic techniques. Samples were allowed to clot at room temperature and then centrifuged to separate serum, which was aliquoted and stored at −80°C until analysis. Serum growth hormone (GH) and insulin-like growth factor-1 (IGF-1) concentrations were measured using commercially available enzyme-linked immunosorbent assay (ELISA) kits validated for pediatric use, following the manufacturers' instructions. All samples from a given participant (pre and post) were analyzed in the same assay run to reduce inter-assay variability, and all measurements were performed in duplicate. Intra-assay and inter-assay coefficients of variation were maintained below 8 percent for both GH and IGF-1.

Statistical Analysis

All statistical analyses were performed using SPSS software (Version XX, IBM Corp., Armonk, NY, USA). Data were first inspected for outliers and checked for normality using the Shapiro–Wilk test. Descriptive statistics are presented as mean ± standard deviation for all variables. Baseline differences between the training and control groups in anthropometric and hormonal measures were examined using independent samples t-tests. To evaluate the effects of the endurance swimming program on GH and IGF-1, a two-way repeated measures analysis of variance (group × time) was conducted, with group (swimming vs. control) as the between-subjects factor and time (pre vs. post) as the within-subjects factor. When significant interaction or main effects were detected, Bonferroni-adjusted post hoc comparisons were performed to identify specific differences. Effect sizes were calculated as partial eta squared for ANOVA and Cohen's d for pairwise comparisons to quantify the magnitude of changes. The level of statistical significance was set at $p < 0.05$ for all tests. Additionally, Pearson correlation coefficients were computed to explore associations between changes in GH and IGF-1 and changes in BMI or other relevant anthropometric variables.

Results

Participant Characteristics

In this study, thirty children were divided into two groups (15 in the swimming group and 15 in the control group). At baseline, the two groups did not differ significantly in any of the anthropometric characteristics, indicating a good balance of groups before the intervention (Table 1).

Table 1: Baseline Anthropometric Characteristics of Participants

Variable	Swimming Group (n = 15)	Control Group (n = 15)	p-value
Age (years)	9.6 ± 0.5	9.5 ± 0.6	0.71
Height (cm)	138.2 ± 6.1	137.5 ± 5.8	0.68
Weight (kg)	32.4 ± 4.3	32.9 ± 4.6	0.77
BMI (kg/m²)	16.9 ± 1.5	17.1 ± 1.6	0.64
Body fat (%)	20.2 ± 3.0	20.6 ± 3.2	0.73
Lean mass (kg)	25.7 ± 3.0	25.9 ± 2.9	0.82

A two-way repeated-measures ANOVA revealed a significant group × time interaction for serum growth hormone (GH) levels ($F(1,28)=19.63$, $p<0.001$). As shown in Table 2, GH increased markedly in the swimming group from 17.4±0.9 to 22.9±1.1 ng/mL (within-group $p<0.001$), whereas no significant change was observed in the control group (17.5±1.0 to 17.7 ±1.1 ng/mL, $p=0.384$). The between-group comparison of changes confirmed a significantly greater increase in GH for the swimming group ($p<0.021$).

For insulin-like growth factor-1 (IGF-1), a smaller but statistically significant group × time interaction was found ($F(1,28)=5.62$, $p=0.025$). Children in the swimming group demonstrated a significant rise in IGF-1 from 212.3±24.5 to 232.8±26.1 ng/mL ($p=0.018$), while the control group showed no meaningful change over time (214.1±25.3 to 216.0±25.0 ng/mL, $p = 0.413$). Between-group comparison indicated that the change in IGF-1 was significantly greater in the swimming group ($p=0.027$).

No significant differences were observed between groups for changes in BMI, body mass, or total body fat percentage (all $p>0.10$). Although the swimming group exhibited a slight reduction in body fat and a modest improvement in lean mass, these changes did not reach statistical significance. Overall, the findings demonstrate that eight weeks of moderate-intensity endurance swimming induced significant elevations in GH and IGF-1 in prepubertal children, independent of major anthropometric changes (Table 2).

Table 2: Serum Growth Hormone (GH) and Insulin-Like Growth Factor-1 (IGF-1) Before and After 8-Week Endurance Swimming Training in Children (ANOVA)

Variable	Group	Pre (mean ± SD)	Post (mean ± SD)	P-value	F (Group × Time)
GH (ng/mL)	Swimming	17.4 ± 0.9	22.9 ± 1.1	0.001*	19.63
	Control	17.5 ± 1.0	17.7 ± 1.1	0.384	
P-value		0.754	0.021*	-	
IGF-1 (ng/mL)	Swimming	212.3 ± 24.5	232.8 ± 26.1	0.018*	5.62
	Control	214.1 ± 25.3	216.0 ± 25.0	0.413	
P-value		0.589	0.027*	-	

* Signs of significant change

Discussion

The main findings of this study indicate that eight weeks of moderate-intensity endurance swimming resulted in significant increases in both growth hormone (GH) and insulin-like growth factor-1 (IGF-1) among prepubertal children, while no meaningful hormonal changes occurred in the control group. These results suggest that structured aquatic endurance exercise is capable of stimulating the somatotropic axis during childhood, producing endocrine adaptations independent of major changes in anthropometric parameters (Martinelli et al., 2008; Sepehri Manesh et al., 2021). GH and IGF-1 are key mediators of linear growth, tissue accretion, and metabolic regulation, and their responsiveness to physical activity is especially relevant in the prepubertal years when endocrine systems are still maturing (Cruzat et al., 2008; Eliakim & Nemet, 2020). Importantly, the elevation in GH was more pronounced than the increase observed in IGF-1, indicating that the hormonal response may differ in magnitude or timing between these two components of the GH–IGF-1 axis (Eliakim et al., 2001; Poehlman & Copeland, 1990).

Regarding GH, the results of the present study align with several investigations that have demonstrated increased GH secretion following regular endurance or swimming exercise in children and youth. An 8-week swimming program in boys aged 9–11 years led to a significant increase in GH, similar to the pattern observed in our training protocol based on moderate-intensity continuous swimming (45–65% HRmax) (Sepehri Manesh et al., 2021). Likewise, aerobic and endurance-type programs that engage large muscle groups have been reported to elicit robust GH responses, particularly when exercise is prolonged and performed at moderate-to-vigorous intensity (Buyukyazi et al., 2003; Wideman et al., 2006). The involvement of large muscle mass and the associated metabolic stress, including increased oxygen demand and substrate turnover, appear to be critical determinants of GH release during exercise (Cruzat et al., 2008; Naughton et al., 2000).

However, other studies have reported contrasting outcomes. Some endurance interventions in children and adolescents have failed to show

significant chronic increases in GH, or have demonstrated only modest changes, especially when training was of shorter duration, lower intensity, or performed under conditions that blunted physiological stress (Naughton et al., 2000; Nazari & Shabani, 2018). Moreover, research in artistic and rhythmic gymnasts has suggested that very high training volumes and energy imbalance may even be associated with growth retardation and altered GH dynamics (Georgopoulos et al., 2002). High-volume or very intense exercise can also promote a predominantly catabolic milieu, characterized by elevations in inflammatory cytokines and stress hormones, which may attenuate or blunt GH responses over time (Nemet et al., 2002; Zaldivar et al., 2006). These conflicting results highlight the role of training load, environmental conditions, and maturation status in shaping GH secretion. In the context of the current study, the significant rise in GH can likely be attributed to the moderate intensity (45–65% HRmax), adequate program duration (eight weeks), and whole-body activation achieved through continuous swimming, which collectively produced sufficient physiological stress to stimulate GH secretion without inducing the catabolic suppression sometimes seen in overreaching or overtraining scenarios (Buyukyazi et al., 2003; Wideman et al., 2006).
For IGF-1, the present findings also revealed a significant, albeit smaller, increase after the swimming training program. This result is consistent with evidence from endurance- and training-related studies in youth and adults showing that improvements in fitness, favorable changes in body composition, and progressive adaptation to training can support increases in circulating IGF-1 over the course of several weeks or months (Koziris et al., 1999; Chicharro et al., 2001; Tourinho Filho et al., 2017; Pisa et al., 2020). Long-term training in swimmers and other athletes has been associated with elevated total and free IGF-1, as well as higher IGFBP-3 levels, particularly after sufficient time has elapsed for a shift from an initial catabolic phase to a more anabolic steady state (Koziris et al., 1999; Tourinho Filho et al., 2017). Similarly, chronic endurance or mixed training programs in team-sport athletes have reported either improved or maintained IGF-1 across a

competitive season when training load and recovery were well managed (Mejri et al., 2005; Pisa et al., 2020).

Nevertheless, several studies contradict these outcomes, reporting no change or even reductions in IGF-1 in response to relatively intense or short-term training in youth. Intensive aerobic or field-based training in adolescent girls and boys has been shown to result in decreased serum IGF-1, coupled with increased pro-inflammatory cytokines and inhibitory binding proteins, reflecting a predominantly catabolic state (Eliakim et al., 2001; Nemet et al., 2002; Scheett et al., 2003, as cited in Alipio & Tourinho Filho, 2025). In prepubertal children, high-frequency aerobic exercise over a few weeks has been associated with reductions in IGF-1 and IGFBP-3, along with increases in IL-1β, TNF-α, and IGFBP-1 or IGFBP-2 (Nemet et al., 2002; Zaldivar et al., 2006). Such changes may represent an early training phase in which catabolic influences temporarily predominate before longer-term adaptations emerge (Alipio & Tourinho Filho, 2025). These discrepancies are likely due to differences in training density, maturation stage, cytokine responses, nutritional status, and the timing of blood sampling relative to exercise and recovery (Naughton et al., 2000; Almalki et al., 2022). In the present study, the moderate training load, three weekly sessions with appropriate recovery, and the 48-hour post-exercise sampling window may have allowed IGF-1 levels to reflect the cumulative anabolic adaptations of training, rather than acute catabolic responses immediately after exercise (Koziris et al., 1999; Tourinho Filho et al., 2017). Therefore, the observed IGF-1 increase can be interpreted as a favorable hormonal adjustment to an appropriately designed endurance swimming program.

Overall, the findings of this study support the beneficial role of moderate-intensity endurance swimming in enhancing the somatotropic hormonal profile of children. By eliciting a robust GH response and a modest increase in IGF-1 without evidence of catabolic suppression, the training protocol appears compatible with healthy growth and endocrine development in prepubertal participants (Martinelli et al., 2008; Sepehri Manesh et al., 2021). At the same time, the broader

literature emphasizes that hormonal responses to training are highly sensitive to exercise intensity, volume, duration, and the developmental stage of the child or adolescent (Naughton et al., 2000; Eliakim et al., 2001; Georgopoulos et al., 2002). These factors, along with adequate energy intake and recovery, should be carefully considered when designing pediatric exercise programs aimed at promoting healthy growth, optimizing the GH–IGF-1 axis, and minimizing the risk of adverse endocrine or growth-related outcomes (Cruzat et al., 2008; Eliakim & Nemet, 2020; Georgopoulos et al., 2002).

Conclusion

The findings of this study suggest that appropriately prescribed aquatic endurance training can beneficially stimulate the somatotropic axis without major changes in body size. Overall, the results support the use of structured swimming programs as a safe and effective strategy for promoting endocrine and growth-related health in childhood.

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Conflicts of Interest:

There are no conflicts of interest.

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