EFFECTS OF AN INTEGRATED STRENGTH AND TECHNICAL TRAINING PROTOCOL ON BACKSTROKE START PERFORMANCE IN ADOLESCENT COMPETITIVE SWIMMERS

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Abstract: Backstroke start performance is a decisive determinant of sprint swimming success, particularly during the first 15 m of the race. Dry-land strength training has been shown to improve neuromuscular performance; however, evidence regarding its transfer to backstroke-specific start performance in adolescent swimmers remains limited. The purpose of this study was to investigate the effects of an integrated strength and technical training protocol on 15-m backstroke start performance, medicine ball push, half squat performance, and vertical jump performance in competitive swimmers aged 14–15 years.
Thirty competitive swimmers were allocated to an experimental group (n = 15) or a control group (n = 15). Both groups followed the same in-water swimming program throughout the competitive season, whereas the experimental group additionally completed a structured dry-land strength program combined with sport-specific technical training. Performance was assessed at baseline (Pre), mid-intervention (Mid), and post-intervention (Post). Repeated-measures ANOVA was used to evaluate the effects of Time, Group, and the Group × Time interaction.
Significant improvements were observed in all performance variables over time ($p < .001$). Significant Group × Time interactions demonstrated that the experimental group achieved substantially greater improvements than the control group in medicine ball push, half squat performance, vertical jump height, and 15-m backstroke start time (all $p < .001$). Although both groups demonstrated small improvements throughout the intervention, the experimental group showed markedly greater gains, with the largest improvement observed in 15-m backstroke start performance.
These findings indicate that integrating structured dry-land strength training with additional backstroke-specific technical practice effectively enhances both neuromuscular performance and swimming-specific start performance in adolescent competitive swimmers. The results support the inclusion of integrated dry-land strength training within long-term swimmer development programs to optimize competitive backstroke performance.
Keywords: adolescent swimmers; backstroke start; dry-land strength training; swimming performance; technical training.

1. INTRODUCTION

Competitive swimming performance depends not only on free-swimming velocity but also on the effectiveness of the start, underwater phase, turns, and finish. Among these race components, the start is particularly important because it enables swimmers to achieve velocities greater than those attained during surface swimming and can substantially influence overall race performance, especially in sprint events. Consequently, the time required to reach the 15-m mark is widely accepted as a valid indicator of start effectiveness and competitive performance (Born, Kuger, Polach, & Romann, 2024).

Unlike the ventral swimming strokes, the backstroke start is initiated from an in-water position and requires coordinated force production by the upper and lower limbs against the starting grips, pool wall, and backstroke starting ledge. Successful execution depends on explosive take-off, optimal body alignment during flight, efficient water entry, and maintenance of velocity throughout the underwater phase. Previous biomechanical studies have identified take-off velocity, force production, body position, foot placement, and start configuration as key determinants of 15-m backstroke start performance (de Jesus, de Jesus, Figueiredo, & Gonçalves, 2013; de Jesus, Fernandes, Vilas-Boas, & Sanders, 2014; de Jesus et al., 2016).

Because of these biomechanical demands, backstroke start performance relies heavily on maximal strength, explosive power, and neuromuscular coordination. Systematic dry-land strength training has become an essential component of modern swimming preparation, as it enhances muscular strength, force production, and explosive power, particularly during adolescence, when neuromuscular adaptations are pronounced (Lekina, 2021; Lekina, 2022). However, improvements in general physical fitness do not always transfer directly to swimming performance, highlighting the importance of combining dry-land strength development with sport-

specific technical practice. Such an integrated approach may facilitate the transfer of neuromuscular adaptations to swimming-specific performance and improve start effectiveness beyond that achieved through conventional swimming training alone (Bishop, Smith, Smith, & Rigby, 2009).
Although previous studies have examined the biomechanics of the backstroke start and the effects of isolated strength or plyometric training, limited evidence is available regarding the longitudinal effects of an intervention integrating structured dry-land strength training with additional backstroke-specific technical practice in adolescent competitive swimmers. Furthermore, few investigations have simultaneously evaluated adaptations in upper-body explosive strength, lower-body strength, lower-body power, and backstroke start performance within the same training programme. Previous work has also emphasized the importance of systematic technical preparation during the developmental years as a key factor for long-term swimming performance (Lekina, 2023).
Therefore, the purpose of the present study was to examine the effects of an Integrated Strength and Technical Training Protocol (ISTTP) on medicine ball push performance, half squat performance, vertical jump performance, and 15-m backstroke start performance in competitive adolescent swimmers. It was hypothesized that swimmers who completed the integrated intervention in addition to their regular swimming training would demonstrate greater improvements in all dry-land performance measures and significantly faster 15-m backstroke start performance than swimmers who followed conventional training alone.

2. MATERIALS AND METHODS

2.1. Participants

Thirty competitive adolescent swimmers specializing in backstroke (16 males and 14 females; aged 14–15 years) participated in this controlled longitudinal study. All participants were registered members of two regional swimming clubs in Greece, trained systematically throughout the competitive season under the supervision of their respective coaches, and regularly competed in regional and national championships. Swimmers were allocated to either the experimental group (EG; n = 15) or the control group (CG; n = 15) according to club affiliation, with each group comprising eight males and seven females. Inclusion criteria included regular participation in competitive swimming, medical clearance for sports participation, and the absence of musculoskeletal injuries or medical conditions affecting training or testing. Written informed consent was obtained from all participants and their parents or legal guardians prior to participation. The study was conducted in accordance with the Declaration of Helsinki, and all participants completed the intervention and testing protocol.

2.2. Study Design

The study employed a controlled, longitudinal, non-randomized parallel-group design to investigate the effects of an Integrated Strength and Technical Training Protocol (ISTTP) on performance in adolescent competitive backstroke swimmers. The intervention was conducted over one competitive season (October 2025–July 2026), with assessments performed at baseline (Pre), mid-intervention (Mid), and post-intervention (Post). Baseline assessments included anthropometric measurements, whereas medicine ball push, half squat, vertical jump, and 15-m backstroke start performance were evaluated at all three time points. To minimize the influence of fatigue and ensure measurement consistency, dry-land and swimming performance tests were conducted on separate days under standardized conditions using the same equipment, testing procedures, and evaluator throughout the study.

2.3. Training Intervention

2.3.1. Control Group

Participants in the control group followed the regular swimming training programme implemented by their respective clubs throughout the competitive season. Training was performed six days per week according to the annual periodized programme and included conventional dry-land conditioning consisting of circuit-based exercises and aerobic running to maintain general fitness, muscular strength, endurance, and mobility. No structured plyometric exercises or additional backstroke-specific technical training targeting starts, turns, underwater swimming, or sprint performance were included.

2.3.2. Experimental Group

In addition to the same regular swimming programme followed by the control group, participants in the experimental group completed an Integrated Strength and Technical Training Protocol (ISTTP) throughout the competitive season. The dry-land component followed the progressive strength training protocol previously described by (Kanelov & Gotsi, 2024), targeting maximal strength, explosive power, core stability, and neuromuscular coordination. The technical component consisted exclusively of backstroke-specific training and focused on repeated practice of backstroke starts, turns, underwater dolphin kicking, and short-distance sprint swimming. Training content was periodized according to the objectives of each phase of the annual training programme. Thus, the only systematic difference between the two groups was the implementation of the ISTTP.

2.4. Outcome Measures

2.4.1. Anthropometric Measurements

Baseline anthropometric assessments included age, standing height, body mass, and body fat percentage. Standing height was measured to the nearest 0.1 cm using a portable stadiometer, while body mass and body fat percentage were assessed using a Tanita BC-545N bioelectrical impedance analyzer (Tanita Corporation, Tokyo, Japan). All measurements were obtained under standardized conditions before physical performance testing and were recorded only at baseline to characterize the study sample.

2.4.2. Dry-Land Performance Tests

Dry-land performance was evaluated at Pre, Mid, and Post using three standardized field tests assessing upper-body explosive strength (Medicine Ball Push), lower-body strength (Half Squat), and lower-body explosive power (Vertical Jump). Following a standardized warm-up, participants completed two familiarization attempts before testing. All assessments were performed under identical conditions by the same evaluator, and the best performance was retained for statistical analysis.

2.4.2.1. Medicine Ball Push

Upper-body explosive strength was assessed using the Medicine Ball Push (MBP) test adapted from Clemons et al. (2010). Participants performed the test on a 45° inclined bench using a 6-kg medicine ball (females) or a 9-kg medicine ball (males). Two maximal trials separated by at least 2 min of passive recovery were completed, and the greatest throwing distance (cm) was retained for analysis.

2.4.2.2. Half Squat

Lower-body strength was evaluated using a Half Squat (HS) test performed on a Smith machine (Multipower Fitness Line, Panatta) with a load corresponding to 30% of each participant's one-repetition maximum (1RM). Participants completed three consecutive repetitions, and execution time was determined by frame-by-frame analysis of recordings obtained with a GoPro HERO11 Black camera. The fastest repetition was used for statistical analysis.

2.4.2.3. Vertical Jump

Lower-body explosive power was assessed using the Sargent Vertical Jump test (Sargent, 1921). Participants performed two maximal countermovement jumps with arm swing, and jump height was calculated as the difference between standing reach and maximal jump reach.

2.4.3. 15-m Backstroke Start Performance

Backstroke start performance was evaluated as the time required to reach the 15-m mark following a standard competitive backstroke start in a 50-m indoor swimming pool, in accordance with World Aquatics Competition Regulations (World Aquatics, 2025). Each swimmer performed two maximal trials separated by a 25-min active recovery period. Before the second trial, capillary blood lactate concentration was measured using a Lactate Plus Meter (Nova Biomedical, USA), and testing resumed only when lactate concentration was ≤ 3 mmol·L^{-1}. If this criterion was not met, measurements were repeated every 3–5 min until recovery. Performance time was recorded manually using a FINIS 3X-300M competition stopwatch (0.01 s resolution), and the fastest trial was retained for statistical analysis.

2.5. Statistical Analysis

Data are presented as mean ± standard deviation (SD). Baseline differences between the experimental and control groups in continuous variables were examined using independent-samples *t*-tests. Changes in medicine ball push performance, half squat performance, vertical jump height, and 15-m backstroke start time were analyzed using a two-way repeated-measures analysis of variance (ANOVA), with **Time** (Pre, Mid, and Post) as the within-subject factor and **Group** (experimental and control) as the between-subject factor. When significant main effects or Group × Time interactions were identified, Bonferroni-adjusted pairwise comparisons were performed. Effect sizes were expressed as partial eta squared (η_p^2). Statistical significance was set at $p < .05$.

3. RESULTS

Baseline characteristics of the participants are presented in **Table 1**. No significant between-group differences were observed for age, body height, body mass, body fat percentage, training experience, or sex distribution (all $p > .05$), confirming that the experimental and control groups were comparable before the intervention.

Table 1. Baseline characteristics of the participants.

Variable	Experimental (n = 15)	Control (n = 15)	p-value
Sex (M/F)	8/7	8/7	—
Age (years)	14.60 ± 0.51	14.53 ± 0.52	.724
Body height (cm)	168.67 ± 4.81	168.53 ± 5.04	.941
Body mass (kg)	60.24 ± 4.89	60.31 ± 5.19	.969
Body fat (%)	14.29 ± 3.85	14.03 ± 3.89	.859
Training experience (years)	7.07 ± 1.28	7.07 ± 1.28	1.000

Note. Data are presented as mean ± standard deviation (SD). Group comparisons were performed using independent-samples *t*-tests.

Source: Authors' research

Changes in dry-land performance variables are presented in **Table 2**. Repeated-measures ANOVA revealed significant main effects of **Time** (all $p < .001$) and significant **Group × Time** interactions (all $p < .001$) for medicine ball push, half squat performance, and vertical jump height, whereas no significant main effects of **Group** were observed (all $p > .05$). Bonferroni-adjusted post hoc comparisons demonstrated significant improvements throughout the intervention period in both groups; however, the experimental group consistently exhibited significantly greater improvements than the control group across all dry-land performance measures.

Table 2. Changes in dry-land performance variables (mean ± SD).

Variable	Group	Pre	Mid	Post
Medicine Ball Push (m)	CON	3.712 ± 0.669	3.733 ± 0.670	3.759 ± 0.671
	EXP	3.717 ± 0.667	3.793 ± 0.676	3.880 ± 0.687
Half-Squat Time (s)	CON	1.251 ± 0.094	1.241 ± 0.094	1.231 ± 0.094
	EXP	1.248 ± 0.090	1.208 ± 0.090	1.167 ± 0.091
Vertical Jump Height (cm)	CON	32.23 ± 3.51	32.64 ± 3.56	33.11 ± 3.58
	EXP	32.41 ± 3.24	33.92 ± 3.40	35.49 ± 3.54

Note. Values are presented as mean ± SD. CON = control group; EXP = experimental group.

Source: Authors' research

Changes in 15-m backstroke start performance are presented in **Table 3** and **Figure 1**. Repeated-measures ANOVA demonstrated a significant main effect of **Time** ($F(2,56) = 574.256$, $p < .001$, $\eta p^2 = .954$) and a significant **Group × Time** interaction ($F(2,56) = 276.263$, $p < .001$, $\eta p^2 = .908$), whereas the main effect of **Group** was not significant ($F(1,28) = 1.927$, $p = .176$, $\eta p^2 = .064$). Bonferroni-adjusted pairwise comparisons revealed no significant between-group differences at baseline ($p = .343$) or mid-intervention ($p = .073$). However, the experimental group achieved significantly faster 15-m backstroke start times at post-intervention ($p = .002$). Although both groups improved throughout the intervention period, the experimental group demonstrated substantially greater reductions in 15-m backstroke start time, indicating the superior effectiveness of the Integrated Strength and Technical Training Protocol (ISTTP).

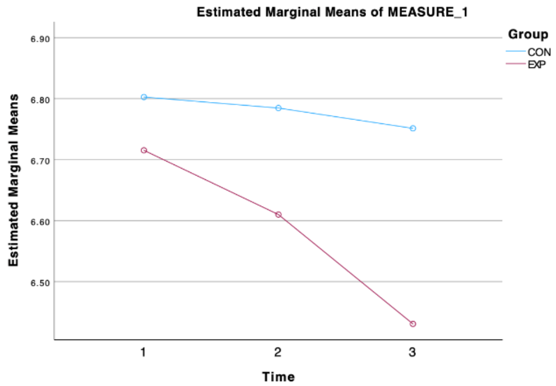
Table 3. Changes in 15-m backstroke start performance (mean ± SD).

Group	Pre (s)	Mid (s)	Post (s)
Control (n = 15)	6.803 ± 0.241	6.785 ± 0.243	6.751 ± 0.245
Experimental (n = 15)	6.715 ± 0.255	6.610 ± 0.270	6.431 ± 0.267

Note. Values are presented as mean ± SD. CON = control group; EXP = experimental group. Lower values indicate better performance.

Source: Authors' research

Figure 1. Changes in 15-m backstroke start performance across the three assessment points in the control (CON) and experimental (EXP) groups.



Source: Authors' research

4. DISCUSSION

The present study investigated the effects of an Integrated Strength and Technical Training Protocol (ISTTP) on dry-land performance and 15-m backstroke start performance in adolescent competitive swimmers. The principal finding was that swimmers who completed the integrated intervention demonstrated significantly greater improvements in medicine ball push performance, half squat performance, vertical jump height, and 15-m backstroke start performance than those who followed conventional swimming training alone.

The greatest improvement was observed in 15-m backstroke start performance, supporting the effectiveness of integrating structured dry-land strength training with backstroke-specific technical practice. This finding is consistent with previous studies identifying the 15-m start time as a key determinant of sprint swimming performance and emphasizing the importance of force production, take-off mechanics, and underwater efficiency during the backstroke start (Born et al., 2024; de Jesus et al., 2014). The superior improvements observed in the experimental group suggest that increased neuromuscular capacity, combined with repeated sport-specific technical practice, enhanced the transfer of dry-land adaptations to swimming performance.

Significant improvements in medicine ball push, half squat performance, and vertical jump height further demonstrate the effectiveness of the integrated training approach for developing upper-body explosive strength, lower-body strength, and lower-body power. These physical adaptations are likely to have contributed to the improved force application during the backstroke start and to more effective start execution. Similar findings have been reported following dry-land strength and plyometric training programmes combined with swimming-specific practice (Bishop et al., 2009; Thng et al., 2019). Collectively, these findings support the integration of structured dry-land strength and backstroke-specific technical training within long-term swimmer development programmes.

Several limitations should be acknowledged. The sample size was relatively small, participants were allocated according to club affiliation rather than randomization, and only overall 15-m backstroke start performance was evaluated. Future research should include larger randomized samples and comprehensive biomechanical analyses to further clarify the mechanisms underlying the observed performance improvements.

5. CONCLUSIONS

The present study demonstrated that an Integrated Strength and Technical Training Protocol (ISTTP) produced significantly greater improvements in medicine ball push performance, half squat performance, vertical jump height, and 15-m backstroke start performance than conventional swimming training alone in adolescent competitive swimmers. These findings indicate that combining structured dry-land strength training with backstroke-specific technical practice effectively enhances neuromuscular performance and facilitates its transfer to swimming-specific start performance. From a practical perspective, integrating age-appropriate dry-land strength training with systematic backstroke-specific technical practice is recommended as an effective strategy for improving start performance and supporting the long-term athletic development of adolescent competitive swimmers.

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