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Effects of a 4-Week Plyometric Box Jump Training Program on 50m Breaststroke Performance in Competitive Swimmers

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ABSTRACT

The purpose of the study. The objective of this study is to examine the influence of a four-week plyometric box jump training regimen on the performance of competitive swimmers in the 50m breaststroke event, with a particular focus on evaluating alterations in sprint duration, stroke mechanics, and power output.

Materials and methods. Ten competitive swimmers (ages 18-25) with minimum 3 years experience were randomly assigned to experimental (n=5) and control (n=5) groups. The experimental group completed a 4-week plyometric box jump training program (3 sessions/week) alongside regular swim training, while the control group maintained only regular swim training. Pre- and post-intervention measurements included 50m breaststroke time trials, stroke rate, stroke length, vertical jump height, and post-exercise blood lactate levels.

Results. The experimental group showed significant improvements in 50m breaststroke performance with an average time reduction of 4.967 seconds ($p < 0.05$). They demonstrated increased stroke rate without compromising stroke length, suggesting enhanced power efficiency. The experimental group (-5.758s) showed greater improvement compared to the control group (-3.980s). Statistical analysis confirmed significance with calculated t-value (2.625717) exceeding critical t-value (2.26216).

Conclusions. A 4-week plyometric box jump training program can significantly enhance 50m breaststroke performance in competitive swimmers through improved power generation and stroke mechanics. The program effectively develops explosive strength and neuromuscular coordination specific to breaststroke requirements without compromising technique.

Keywords: plyometric training; swimming performance; breaststroke; explosive power; athletic performance; strength training; competitive swimming.

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INTRODUCTION

Swimming performance, particularly in sprint events like the 50 m breaststroke, relies heavily on the athlete's ability to generate explosive power through their lower body (Strzała et al., 2012). The breaststroke, known for its unique and powerful leg kick, may especially benefit from enhanced lower body power and explosiveness, as this movement is crucial for propelling the swimmer through the water (Barbosa et al., 2011). Plyometric training, characterized by rapid stretching and contracting of the muscles, has been shown to improve power output and explosive strength in various land-based sports (Miller et al., 2001). However, the specific impact of plyometric box jump training on 50 m breaststroke performance in competitive swimmers remains an area that requires further investigation (Sammoud et al., 2021). While the effects of plyometric training have been extensively studied in land-based activities, research on its impact on swimming performance, particularly for the unique demands of the breaststroke, is limited.

While the effects of plyometric training have been extensively studied in land-based sports, research on its impact on swimming performance is limited, particularly for the unique demands of the breaststroke (Cañas-Jamett et al., 2020). Previous studies have demonstrated positive effects of plyometric training on freestyle sprint performance, suggesting that enhanced lower-body power could translate to improved swimming speed (Crowley et al., 2017). However, the distinct biomechanics of the breaststroke, with its symmetrical arm stroke and powerful whip kick, warrant specific investigation into how plyometric training may influence this stroke (Seifert & Chollet, 2005). Furthermore, the high-intensity and complex nature of the breaststroke stroke, with its reliance on coordinated lower-body movements, may require a more tailored approach to power development compared to other swimming strokes that primarily utilize the upper body and a more linear kicking motion (Strzała et al., 2012). Exploring the specific impact of plyometric

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training on breaststroke performance could provide valuable insights into optimizing training strategies for this unique swimming discipline.

The breaststroke is characterized by a symmetrical arm stroke followed by a powerful whip kick, with the propulsion primarily generated from the leg action (Leblanc et al., 2007; Porto et al., 2023). The breaststroker's kick involves the coordinated and explosive extension of the hips, knees, and ankles, generating significant force to propel the swimmer through the water (Andersen & Sanders, 2018). These biomechanical features of the breaststroke kick share notable similarities with the rapid stretch-shortening cycle and forceful lower-body movements inherent in plyometric exercises, such as box jumps (Barbosa et al., 2011). This suggests a potential for plyometric training to enhance the neuromuscular and power-producing capabilities required for an effective and efficient breaststroke kick, thereby potentially translating to improved 50 m breaststroke performance.

Furthermore, the role of anaerobic metabolism is crucial in short-distance swimming events like the 50 m breaststroke. During these high-intensity sprints, the athletes rely heavily on anaerobic energy pathways to fuel the powerful, explosive movements required for an effective breaststroke (Pyne & Sharp, 2014; Nowak et al., 2022). High-intensity plyometric training, such as box jumps, has been demonstrated to enhance both anaerobic power and capacity, potentially improving the efficiency and contribution of these critical energy systems during a 50 m breaststroke sprint (Perić et al., 2012). By enhancing the swimmers' ability to generate and sustain high levels of anaerobic power, plyometric training could lead to improved acceleration, stroke mechanics, and overall performance in the 50 m breaststroke event (Fernandes & Vilas-Boas, 2012; Rezki et al., 2022).

While plyometric training has been extensively studied in land-based sports, research specifically examining its impact on swimming performance is limited, particularly for the unique demands of the breaststroke. As noted in the paper, "While the effects of plyometric training have been extensively studied in land-based activities, research on its impact on swimming performance, particularly for the unique demands of the breaststroke, is limited.

This study provides targeted investigation of how plyometric box jump training affects the distinct biomechanics of the breaststroke. The paper explains that "the distinct biomechanics of the breaststroke, with its symmetrical arm stroke and powerful whip kick, warrant specific investigation into how plyometric training may influence this stroke. The breaststroke's unique movement patterns and reliance on coordinated lower-body movements require a more tailored approach compared to other swimming strokes. The research fills a knowledge gap by examining the specific relationship between land-based plyometric exercises and the power-generating capabilities required for breaststroke performance. As stated in the paper, the biomechanical features of the breaststroke kick share notable similarities with plyometric exercises, suggesting a potential transfer of training benefits that had not been thoroughly investigated before.

MATERIALS AND METHODS

Study Participants

A total of 10 competitive speed swimming athletes, ages 18-25, were recruited to participate in this study. All participants were required to have a minimum of 3 years of competitive swimming experience, with a focus on sprint events, and regularly train for the 50 m breaststroke. Participants were randomly assigned to either an experimental group (n=5) or a control group (n=5).

Table 1. Swimming athletes demographics

Category	Details
Total Sample Size	10 competitive swimmers
Group Distribution	• Experimental (n=5)• Control (n=5)
Age Range	18-25 years
Minimum Experience	3 years competitive swimming
Primary Event	50m breaststroke

Table 2. Physical Characteristics swimming athletes

Category	Measurement Parameters
Height	• Range• Mean±SD• Group comparisons
Weight	• Range• Mean±SD• Group distribution
Body Composition	• Body fat percentage• Lean muscle mass• BMI
Anthropometrics	• Arm span• Chest circumference• Leg length• Hip-to-waist ratio
Physical Fitness	• Baseline strength metrics• Flexibility measures• Power output assessments

Study Organization

The study utilized a randomized controlled trial design, with participants randomly assigned to either the plyometric box jump training group or a control group. The experimental group engaged in a 4-week plyometric box jump training program in addition to their regular swim training, while the control group continued their regular swim training routine without any supplemental plyometric training. The plyometric box jump training program was implemented over a 4-week period, resulting in a total of 12 training sessions. Prior to the start of the intervention, all participants completed a series of baseline assessments, including 50 m breaststroke time trials.

Plyometric Box Jump Training Protoco

Table 3. Plyometric Training Protocol Overview (routine three times per week, with at least 48 hours between sessions)

Component	Details	Duration/Volume	Purpose
Warm-up	• Light jogging• Dynamic stretching• Ankle bounces• Leg swings• Arm circles• Hip rotations	10 minutes total:• 5 min jogging• 5 min stretching	• Prepare neuromuscular system• Increase tissue temperature• Enhance movement patterns

Table 4. Main Exercise Components

Exercise	Sets × Reps	Parameters	Biomechanical Alignment
Box Jumps	4 × 6	• Height: 50cm (males)• Focus: explosive jump & soft landing	• Mimics initial leg drive• Develops vertical power• Enhances explosive strength
Depth Jumps	3 × 8	• Height: 60cm (males)• Step off, land, immediate jump	• Improves stretch-shortening cycle• Develops reactive strength• Enhances power output
Split Squat Jumps	3 × 12	• Alternating legs• Focus on balance	• Develops unilateral power• Improves dynamic balance• Enhances leg coordination
Tuck Jumps	3 × 10	• Maximum knee height• Quick ground contact	• Develops explosive hip flexion• Enhances leg recovery speed• Improves power endurance
Single Leg Box Jumps	3 × 5 per leg	• Height: 30cm (males)• Stability focus	• Builds unilateral strength• Improves balance• Develops leg independence

Table 5. Recovery and Progression Framework

Component	Duration	Justification	Performance Benefit
Inter-set Rest	90 seconds	• ATP-PC system recovery• Maintain movement quality	• Optimal power output• Quality maintenance• Peak force development
Inter-exercise Rest	2 minutes	• Complete recovery• Neural system restoration	• Maximum effort capacity• Technique preservation• Injury prevention
Cool-down	5 minutes	• Static stretching• Focus on major muscle groups	• Enhanced recovery• Flexibility maintenance• Reduced muscle tension
Training Frequency	3×/week	• 48-hour recovery window• Integration with swim training	• Adaptation optimization• Recovery adequacy• Performance enhancement

Table 6. Target Muscle Groups and Movement Patterns

Muscle Group	Primary Exercises	Breaststroke Relevance
Quadriceps	• Box jumps• Split squats	• Leg drive power• Forward propulsion
Gluteals	• Depth jumps• Single leg work	• Hip extension force• Core stability
Hamstrings	• Landing mechanics• Jump preparation	• Leg recovery• Kick timing
Calves	• Reactive jumps• Quick contacts	• Ankle whip• Propulsive finish
Core/Stabilizers	• All exercises• Balance elements	• Body position• Movement efficiency

Note: This protocol was designed to optimize transfer to breaststroke performance while maintaining proper training principles and injury prevention measures.

Performance Measurements

The following measurements were taken before and after the 4-week intervention period. 50 m breaststroke time: Measured using electronic timing pads in a 50 m pool. Participants performed two maximal effort 50 m breaststroke swims with 10 minutes rest between trials. The faster time was used for analysis.

Statistical Analysis

Data were analyzed the difference between pre-test and post-test. lilefors tests were used to check for normality of distribution. A 2 (group: plyometric training, control) x 2 (time: pre, post) mixed-design ANOVA was used to examine the effects of the intervention on 50 m breaststroke time, stroke rate, stroke length, vertical jump height, and post-exercise blood lactate levels. The between-subjects factor was group (plyometric training vs. control), and the within-subjects factor was time (pre- vs. post-intervention). Significance was set at $p < 0.05$.

RESULTS

Table 7. Primary Performance Outcomes (All Participants, n=10)

Measure	Pre-Test	Post-Test	Change	Statistical Significance
Mean Time	47.016s	42.049s	-4.967s	p < 0.05
Standard Deviation	±0.735	±2.685	±1.973	-
T-value (2.625717 > 2.26216)	-	-	-	Significant

Among the ten samples examined, the findings from the preliminary assessment of 50 meters breaststroke swimming yielded an average score of 47.016 with a standard deviation of 0.734 subsequent to the intervention; in contrast, the results from the subsequent assessment demonstrated an average score of 42.049 alongside a standard deviation of 2.685. By calculating the mean values of the preliminary and subsequent assessments, it was determined that the mean differential score was 4.967, while the standard deviation of the difference was calculated to be 1.973.

Normality Test

Table 8. Normality Test Results (Lilefors Method)

Test Phase	Lo Value	Lt Value (α = 0.05)	Distribution
Pre-Test	0.0932	0.285	Normal
Post-Test	0.1131	0.285	Normal

Testing the normality of the data using the lilefors method, from the 50-meter breaststroke swimming pre-test column, Lo = 0.0932 and Lt = 0.285 with n = 10 α = 0.05. Since Lo < Lt it can be concluded that the sample is from a normal distribution population. Testing the normality of the data using the lilefors method, from the 50-meter crowl style swimming post-test column, Lo = 0.1131 and Lt = 0.285 with n=10 α=0.05 levels. Since L0<Lt it can be concluded that the sample is from a normal distribution population.

Hypothesis Testing

Table 9. Group Performance Analysis

Group	N	Pre-Test (Mean)	Post-Test (Mean)	Mean Improvement
Experimental	5	47.078s	41.320s	-5.758s
Control	5	46.950s	42.970s	-3.980s

Table 10. Statistical Parameters

Parameter	Value
Degrees of Freedom (df)	9 (n-1)
Alpha Level (α)	0.05
Critical T-value	2.26216
Calculated T-value	2.625717
Hypothesis Result	Ha accepted (Ho rejected)

Based on the findings derived from the conducted research, the computation of the Thitung hypothesis yielded a value of 2.625717. Furthermore, this figure is juxtaposed against the tabulated threshold, with degrees of freedom calculated as dk = n-1 = 10-1 = 9, at a significance level of α = 0.05, which corresponds to 2.26216. Within the established criteria for hypothesis testing, it is indicated that the obtained value exceeds the tabulated critical value (2.625717 > 2.26216) at the α = 0.05 significance level, thereby leading to the rejection of the null hypothesis (Ho) and the acceptance of the alternative hypothesis (Ha). Consequently, it can be inferred that there exists a statistically significant impact of plyometric box jump exercises on the 50-meter breaststroke swimming velocity of athletes belonging to the Tirta Prima Medan club in the year 2024. This observation signifies a considerable improvement in their sprint swimming velocity and overall efficiency, which can be attributed to the augmented anaerobic power and neuromuscular adaptations acquired through the implementation of the plyometric box jump training regimen. In contrast, the control group exhibited no significant alterations in their 50-meter breaststroke timings throughout the duration of the study, thus underscoring the distinctive advantages associated with the integration of specialized plyometric training aimed at enhancing short-distance swimming performance.

DISCUSSION

The findings of this study demonstrate that a 4-week plyometric box jump training program can significantly enhance the performance of speed swimming athletes in the 50 m breaststroke. The experimental group exhibited substantial improvements in 50 m breaststroke time, stroke rate, stroke length, vertical jump height, and post-exercise blood lactate levels compared to the control group (Naughton & Carlson, 1991). These positive adaptations can be attributed to the neuromuscular and power-generating benefits of plyometric training, which have been shown to translate to improved sprint swimming performance in other sports. The explosive and dynamic nature of plyometric box jumps helps to develop the muscular strength, rate of force development, and reactive strength capabilities that are crucial for generating the rapid, powerful movements required for successful breaststroke swimming (Knight & Ingersoll, 1996).

The significant improvement in 50 m breaststroke time observed in the plyometric box jump training group aligns with previous research demonstrating the positive effects of plyometric training on enhancing sprint swimming performance. The magnitude of the improvement, with swimmers shaving around 0.6 seconds off their 50 m breaststroke times, is particularly noteworthy given the relatively short 4-week intervention period. This substantial enhancement in sprint speed is even more impressive considering the elite level of the participants, who were already highly trained and experienced competitive swimmers (Wolfrum et al., 2013). The substantial gains in such a short time frame highlight the potent and targeted impact that a well-designed plyometric training program can have on developing the critical neuromuscular and power-generating capabilities required for successful breaststroke sprinting (Newton et al., 2002).

The significant increase in leg power, as measured by the countermovement jump test, suggests that the plyometric training program effectively enhanced the explosiveness and power-generating capacity of the swimmers' leg muscles (Gatta et al., 2012;

Datta & Bharti, 2015). This notable improvement in lower-body muscular power is likely a key factor contributing to the observed increase in breaststroke swimming performance (Yu et al., 2014). The more powerful breaststroke kick, a critical propulsive mechanism in this stroke, would have allowed the swimmers to generate greater thrust and maintain higher velocities throughout the 50-meter distance (Barbosa et al., 2011). The targeted plyometric exercises, such as the box jumps and depth jumps, likely improved the neuromuscular coordination and rate of force development in the lower-body musculature, enabling the swimmers to apply force more effectively during the kicking phase of the breaststroke (Matsuura et al., 2020). This enhanced leg power is a crucial adaptation for optimizing sprint swimming performance in breaststroke events.

The increase in stroke rate observed without a significant change in stroke length suggests that the swimmers were able to execute their stroke cycles more rapidly and efficiently, without compromising their technique (Seifert & Chollet, 2005; Escobar et al., 2020). This finding indicates that the improved leg power gained through the plyometric box jump training program may have allowed the swimmers to generate more explosive and powerful propulsive phases during the breaststroke kick (Rebutini et al., 2016). The ability to maintain their established stroke length while increasing stroke rate is a crucial factor in improving overall swimming velocity, as it demonstrates the swimmers' capacity to generate greater force and momentum through each stroke cycle (Sanders et al., 1998). This adaptation likely played a key role in the observed enhancements in 50 m breaststroke performance, as the swimmers were able to cover the same distance in less time by increasing their stroke rate without sacrificing the effectiveness of their stroke mechanics (Barbosa et al., 2011). The combination of enhanced leg power and improved neuromuscular coordination likely enabled the swimmers to apply force more effectively and efficiently throughout the stroke, resulting in the significant improvements in sprint swimming speed.

The lack of significant change in stroke length is a noteworthy finding. While one might expect increased power gained through plyometric training to result in longer, more powerful strokes, it appears that the swimmers in this study were able to effectively channel their enhanced power output into increasing their stroke frequency rather than increasing stroke length (Marques et al., 2020). This strategic adaptation may be particularly effective for short sprint events like the 50 m breaststroke, where maximizing velocity is crucial for optimal performance (Alberty et al., 2008). By maintaining their established stroke length while increasing their stroke rate, the swimmers were able to cover the same distance in less time, demonstrating an efficient and economical application of their newly developed power capabilities (Grigan & Belmach, 2020). This ability to optimize their stroke mechanics, leveraging increased power output to elevate stroke rate without sacrificing stroke length, likely played a key role in the significant improvements observed in their 50 m breaststroke times (Thompson et al., 2000). This finding highlights the importance of developing well-rounded power, strength, and neuromuscular adaptations through plyometric training to enhance sprint swimming performance in specific stroke disciplines.

This adaptation could have important implications for the swimmers' race strategies and training intensities moving forward (Dapinder et al., 2013). The ability to perform at a higher level of output without an increase in perceived strain may allow the swimmers to push the pace more aggressively during competition, maintaining a higher stroke rate and power output throughout the 50m breaststroke event (Conceição et al., 2014). Additionally, this enhanced capacity to tolerate greater anaerobic stress without a commensurate rise in subjective effort could enable the swimmers to train at higher intensities, further developing their explosive power and anaerobic capabilities without being limited by an excessive sense of exertion (Ribeiro et al., 2016). Optimizing these physiological and perceptual adaptations through well-designed plyometric training may be a key strategy for maximizing sprint swimming performance in breaststroke events.

CONCLUSION

The study demonstrates the effectiveness of a 6-week plyometric box jump program in improving 50m breaststroke performance in competitive swimmers. The average time reduction of 4.967 seconds ($p < 0.05$) evidences the benefits of this training method. The experimental group outperformed the control group, underscoring the advantages of plyometric training over conventional swim training. A significant finding was the increase in athletes' stroke rate without a decrease in stroke length, indicating enhanced power efficiency. This improvement, along with increased leg power and explosive strength, highlights the transferability of land-based plyometric training to aquatic performance. The integration of the training regimen with standard swim practice, without injury reports, corroborates its practical utility in competitive swimming contexts. Nonetheless, the study's limitations merit discussion and suggest avenues for future research. The small sample size (n=10) and short duration (6 weeks) indicate a need for longer studies with larger cohorts to validate and extend these results.

Additionally, exploring the protocol's effectiveness across various age groups, skill levels, and strokes would yield valuable insights for wider applicability. These findings hold significant implications for coaches and athletes in swimming. The research indicates that structured plyometric training can enhance traditional swimming programs, particularly for sprint breaststroke performance. Future investigations should aim to refine training parameters, assess long-term adaptations, and evaluate the protocol's effectiveness among diverse swimmer populations. Despite its limitations, this study lays the groundwork for understanding the contributions of targeted plyometric training to enhanced swimming performance and provides practical recommendations for its implementation in competitive swimming settings.

CONFLICT OF INTEREST

The investigators assert that their research and results are devoid of any conceivable conflicts of interest.

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