ACTA SCIENTIAE Revista de Ensino de Ciências e Matemática ONLINE ISSN 2178-7727 ULBRA

ASSOCIATION BETWEEN BIO-MOTOR ABILITIES AND PERFORMANCE IN 200M INDIVIDUAL MEDLEY: A STUDY OF MALE COMPETITIVE SWIMMERS

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Received: 10th July, 2025
Revised &Accepted: 15th November, 2025
Published: 25th December, 2025
DOI: https://doie.org/10.65985/AS.2026150463

Abstract
Background: Swimming performance in individual medley events depends on multiple physiological and biomechanical factors. Understanding the relationship between bio-motor abilities and competitive performance can inform training strategies and talent identification protocols.
Objective: This investigation aimed to examine the relationship between selected bio-motor abilities and 200m individual medley performance in male swimmers, and to develop a predictive regression model for performance estimation.
Methods: Forty competitive male swimmers (age: 19.80 ± 1.16 years) from Madhya Pradesh, India, participated in this cross-sectional study. All participants had a minimum of five years of competitive swimming experience and were actively training 6-7 hours per week. Bio-motor assessments included bilateral hand grip strength (dynamometry), shoulder flexibility (Bloomfield test), and lower limb explosive power (vertical jump test). Swimming performance was evaluated through timed 200m individual medley trials conducted according to World Aquatics regulations. Pearson correlation coefficients were calculated to examine relationships between variables, and stepwise multiple regression analysis was employed to construct a predictive model ($\alpha = 0.05$).
Results: All examined bio-motor variables demonstrated significant negative correlations with 200m individual medley completion time: left hand grip strength ($r = -0.774$, $p < 0.01$), right hand grip strength ($r = -0.739$, $p < 0.01$), shoulder flexibility ($r = -0.626$, $p < 0.01$), and explosive leg strength ($r = -0.517$, $p < 0.01$). The stepwise regression analysis identified left hand grip strength as the primary predictor, accounting for 60% of the variance in swimming performance ($R^2 = 0.60$, $F = 56.90$, $p < 0.001$). The regression equation was: Performance time (seconds) = 286.76 – 2.28 × (Left Hand Grip Strength).
Conclusions: Left hand grip strength emerged as the most significant predictor of 200m individual medley performance among the examined bio-motor variables. These findings suggest that upper body strength assessment, particularly grip strength, may serve as a valuable tool for talent identification and performance monitoring in male swimmers. Coaches should

incorporate targeted grip strength development within comprehensive training programs to optimize individual medley performance.

Keywords: competitive swimming; individual medley; grip strength; flexibility; explosive power; performance prediction; regression analysis

Introduction

Competitive swimming has maintained its status as a cornerstone Olympic sport since the inaugural modern Games in 1896 [1]. Among swimming disciplines, the individual medley represents one of the most technically and physiologically demanding events, requiring athletes to execute four distinct stroke techniques butterfly, backstroke, breaststroke, and freestyle in sequential order over equal distances [2]. Success in this multifaceted event necessitates a comprehensive integration of technical proficiency, physiological capacity, and bio-motor competencies.

Performance in competitive swimming is determined by a complex interplay of factors encompassing physical capabilities, technical execution, tactical awareness, and psychological resilience [3]. Among these determinants, bio-motor abilities including muscular strength, power output, and joint flexibility constitute fundamental prerequisites for optimal swimming performance. These physical attributes can be systematically developed through evidence-based training protocols that adhere to established principles of exercise physiology and sports conditioning [4].

Bio-Motor Abilities in Swimming Performance

Muscular strength, particularly in the upper body, plays a critical role in generating propulsive forces during swimming. Strength capacity is influenced by multiple factors, including the total number and cross-sectional area of muscle fibers, their contractile tension, and the degree of motor unit recruitment [5]. Hand grip strength, which results from coordinated flexion of finger joints, thumb, and wrist, represents a commonly assessed indicator of overall upper body strength [6]. This measurement reflects the integrated function of 35 muscles comprising the flexor system of the hand and forearm, while wrist stabilization is provided by forearm extensors [7].

Recent systematic reviews have yielded mixed findings regarding the relationship between hand grip strength and swimming performance. Cronin et al. [8] reported stronger associations in younger and adolescent swimmers compared to elite adult populations. These age-related differences may reflect the relative contribution of strength versus technical factors at different competitive levels.

Flexibility, particularly in the shoulder complex, represents another crucial bio-motor component in swimming. The shoulder joint serves as the primary driver of propulsion in most swimming strokes, contributing approximately 90% of forward movement [9]. Restricted shoulder mobility can impede stroke mechanics and limit propulsive efficiency. Walker et al. [10] emphasized the importance of maintaining and enhancing shoulder flexibility to prevent movement compensations and reduce injury risk. Furthermore, Oosterhoff et al. [11] demonstrated significant relationships between shoulder flexibility and stroke velocity, with increased range of motion facilitating greater muscle fiber excursion and force production capacity.

ISSN:1517-4492 | **E-ISSN**:2178-7727

Explosive lower limb power the capacity to generate maximal force at high velocity constitutes another essential bio-motor quality for swimming performance. This attribute is particularly important during starts, turns, and kick phases. Maglischo [12] noted that in breaststroke, approximately 60% of propulsion originates from leg movements, highlighting the substantial contribution of lower body power to overall performance.

Rationale and Research Objectives

Despite the recognized importance of bio-motor abilities in swimming, limited research has systematically examined their collective contribution to individual medley performance, particularly in male swimmers from developing regions. Understanding these relationships can inform talent identification protocols, optimize training program design, and enhance performance prediction accuracy.

The present investigation addressed two primary research questions:

What relationships exist between selected bio-motor parameters (bilateral hand grip strength, shoulder flexibility, and explosive leg strength) and 200m individual medley performance in male swimmers? To what extent do these bio-motor parameters contribute to performance variance, and can they be integrated into a reliable predictive model?

We hypothesized that significant relationships would exist between the examined bio-motor variables and swimming performance, and that these variables would collectively explain a substantial proportion of performance variance in the 200m individual medley event.

Materials and Methods

Study Design and Participants

This cross-sectional correlational study was conducted with competitive male swimmers from Madhya Pradesh, India. The research protocol received approval from the institutional ethics committee, and all procedures adhered to the ethical standards outlined in the Declaration of Helsinki.

Participants: Forty male swimmers (mean age: 19.80 ± 1.16 years) were recruited through purposive sampling from regional swimming clubs. Inclusion criteria required: (1) minimum five years of competitive swimming experience, (2) active training regimen of 6-7 hours per week during the preceding 12 months, (3) regular participation in 200m individual medley events, and (4) age between 17-25 years. Exclusion criteria included: (1) training cessation exceeding one month prior to testing, (2) current musculoskeletal injury, (3) acute or chronic illness affecting physical performance, and (4) use of performance-enhancing substances.

All participants provided written informed consent following a comprehensive explanation of study procedures, potential risks, and benefits. For participants under 18 years of age, parental consent was additionally obtained.

Testing Procedures

All assessments were conducted over two sessions separated by 48-72 hours to minimize fatigue effects. The first session comprised bio-motor ability testing, while the second session involved swimming performance evaluation. Participants were instructed to maintain normal

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training routines, avoid strenuous exercise 24 hours prior to testing, and arrive in a well-hydrated, fed state.

Bio-Motor Assessments

Hand Grip Strength (Bilateral): Maximal isometric grip strength was measured using a calibrated hand-grip dynamometer (accuracy: ±0.1 kg). Following standardized procedures [13], participants stood with the test arm at their side, elbow extended, and forearm in neutral position. The dynamometer was adjusted to fit individual hand size. Participants were instructed to squeeze maximally for 3-5 seconds following a verbal countdown. Three trials were performed for each hand with 60-second rest intervals, and the highest value was recorded for analysis. Testing sequence alternated between dominant and non-dominant hands.

Shoulder Flexibility: Shoulder girdle flexibility was assessed using the modified Bloomfield shoulder flexibility test [14]. Participants held a graduated measuring stick with both hands in a pronated grip while maintaining straight elbows. From an initial position with arms extended anteriorly at shoulder height, participants moved the stick overhead and behind the back in a continuous arc, maximizing shoulder extension while preventing compensatory trunk flexion or elbow bending. The minimum distance between the thumbs (measured in centimeters) that allowed complete movement through the full range represented the flexibility score. Three trials were conducted with 90-second rest periods, and the minimum distance (indicating greatest flexibility) was recorded.

Explosive Leg Strength: Lower limb explosive power was evaluated using the countermovement vertical jump test. Following a standardized warm-up, participants stood on a jump mat with hands on hips to eliminate arm swing contribution. From a standing position, participants performed a rapid downward countermovement followed immediately by maximal vertical propulsion. Jump height was calculated from flight time using validated algorithms [15]. Five trials were performed with 60-second recovery intervals, and the highest jump was recorded for analysis.

Swimming Performance Assessment

The 200m individual medley performance test was conducted in a standard 50-meter pool meeting World Aquatics specifications. Water temperature was maintained between 25-28°C. Following a standardized 15-minute warm-up protocol, participants performed a maximal effort 200m individual medley (50m butterfly, 50m backstroke, 50m breaststroke, 50m freestyle) using an in-water push start. Timing was recorded using electronic touchpads connected to an automatic timing system (precision: 0.01 seconds). Each participant completed a single timed trial, with performance recorded as total completion time in seconds.

Statistical Analysis

Data normality was assessed using the Shapiro-Wilk test ($p > 0.05$ indicating normal distribution). Descriptive statistics (mean, standard deviation, range, skewness, kurtosis) were calculated for all variables. Data distribution was considered normal when skewness and kurtosis values remained within ±2 times their respective standard errors.

Pearson product-moment correlation coefficients were computed to examine bivariate relationships between each bio-motor variable and swimming performance time. The

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magnitude of correlations was interpreted according to established criteria: 0.00-0.30 (weak), 0.31-0.70 (moderate), 0.71-0.90 (strong), and 0.91-1.00 (very strong) [16].

Stepwise multiple linear regression analysis was employed to identify the optimal combination of predictor variables and develop a performance prediction model. Variables were entered based on statistical significance (entry criterion: $p < 0.05$; removal criterion: $p > 0.10$). Model assumptions (linearity, independence of residuals, homoscedasticity, normality of residuals, absence of multicollinearity) were verified through diagnostic procedures. Model fit was evaluated using R^2, adjusted R^2, and F-statistics.

Statistical significance was set at $\alpha = 0.05$ for all analyses. Data processing and statistical computations were performed using IBM SPSS Statistics version 20.0 (IBM Corporation, Armonk, NY, USA).

Results

Descriptive Statistics and Data Distribution

Descriptive statistics for all bio-motor variables are presented in Table 1. Mean hand grip strength values were 38.11 ± 5.72 kg (right hand) and 37.11 ± 6.34 kg (left hand). Mean shoulder flexibility distance was 88.00 ± 21.48 cm, and mean vertical jump height was 48.32 ± 10.25 cm. All variables demonstrated normal distribution characteristics, with skewness and kurtosis values falling within acceptable ranges (less than twice their respective standard errors), confirming the appropriateness of parametric statistical procedures.

Table 1. Descriptive Statistics for Bio-Motor Variables (N = 40)

Variable	Min	Max	Mean	SD	Variance	Skewness	Kurtosis
Right Hand Grip Strength (kg)	25.90	49.00	38.11	5.72	32.75	-0.05	-0.57
Left Hand Grip Strength (kg)	25.20	51.20	37.11	6.34	40.25	0.16	-0.55
Shoulder Flexibility (cm)	39.80	126.10	88.00	21.48	461.53	-0.29	-0.56
Explosive Leg Strength (cm)	20.00	66.00	48.32	10.25	105.04	-0.57	0.15

Note: SD = Standard Deviation; Min = Minimum; Max = Maximum

Correlation Analysis

Pearson correlation analysis revealed significant negative relationships between all examined bio-motor variables and 200m individual medley completion time (Table 2). The negative correlations indicate that higher scores on strength and flexibility measures were associated with faster swimming times (lower completion times).

Left hand grip strength demonstrated the strongest correlation with performance ($r = -0.774$, $p < 0.01$), followed by right hand grip strength ($r = -0.739$, $p < 0.01$), shoulder flexibility ($r = -0.626$, $p < 0.01$), and explosive leg strength ($r = -0.517$, $p < 0.01$). All correlations exceeded the critical value at the 1% significance level (critical $r = 0.403$ for $df = 38$), indicating robust relationships between bio-motor abilities and swimming performance.

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Table 2. Pearson Correlations Between Bio-Motor Variables and 200m Individual Medley Performance (N = 40)

Bio-Motor Variable	Correlation Coefficient (r)	Significance
Right Hand Grip Strength	-0.739**	p < 0.01
Left Hand Grip Strength	-0.774**	p < 0.01
Shoulder Flexibility	-0.626**	p < 0.01
Explosive Leg Strength	-0.517**	p < 0.01

Note: ** Correlation significant at the 0.01 level (2-tailed); Critical value at α = 0.05 (df = 38) = 0.312; Critical value at α = 0.01 (df = 38) = 0.403**

Multiple Regression Analysis

Stepwise multiple regression analysis was conducted to determine the optimal predictive model for 200m individual medley performance. The analysis identified left hand grip strength as the sole significant predictor entering the model (Table 3).

Table 3. Regression Model Summary for Predicting 200m Individual Medley Performance

Model	R	R^2	Adjusted R^2	SEE	R^2 Change	F Change	df1	df2	Sig. F Change
1	0.774	0.60	0.59	11.97	0.60	56.90	1	38	< 0.001

Note: SEE = Standard Error of the Estimate; Predictor: Left Hand Grip Strength; Dependent Variable: 200m Individual Medley Time (seconds)

The regression model explained 60% of the variance in swimming performance ($R^2 = 0.60$, adjusted $R^2 = 0.59$), indicating a substantial proportion of performance variability was accounted for by left hand grip strength alone. The F-statistic was highly significant ($F_{1,38} = 56.90$, $p < 0.001$), confirming the overall model validity (Table 4).

Table 4. Analysis of Variance for the Regression Model

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	8155.31	1	8155.31	56.90	< 0.001
Residual	5446.46	38	143.33		
Total	13601.78	39			

Note: Dependent Variable: 200m Individual Medley Time (seconds); Predictor: Left Hand Grip Strength

The regression coefficients are presented in Table 5. The unstandardized coefficient for left hand grip strength (B = -2.28, SE = 0.30) was statistically significant (t = -7.54, $p < 0.001$), indicating that each 1 kg increase in left hand grip strength was associated with a 2.28-second reduction in 200m individual medley completion time.

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Table 5. Regression Coefficients for the Predictive Model

Variable	Unstandardized B	SE	Standardized β	t	p	Correlations		
Zero-order	Partial	Part						
Constant	286.76	11.37	—	25.22	< 0.001	—	—	—
Left Hand Grip Strength	-2.28	0.30	-0.774	-7.54	< 0.001	-0.774	-0.774	-0.774

Note: SE = Standard Error; Dependent Variable: 200m Individual Medley Time (seconds)

Predictive Equation

Based on the regression analysis, the following equation was derived for predicting 200m individual medley performance in male swimmers:

Predicted Time (seconds) = 286.76 – 2.28 × (Left Hand Grip Strength in kg)

This equation demonstrates practical utility for coaches and sport scientists in estimating individual medley performance based on a simple, accessible field test of upper body strength.

Discussion

The present investigation examined relationships between selected bio-motor abilities and 200m individual medley performance in competitive male swimmers. The principal findings indicate that: (1) all examined bio-motor variables demonstrated significant correlations with swimming performance, (2) left hand grip strength emerged as the strongest single predictor, and (3) a regression model incorporating left hand grip strength explained 60% of performance variance.

Hand Grip Strength and Swimming Performance

The observed strong negative correlation between hand grip strength and swimming time ($r = -0.739$ to -0.774) aligns with previous research demonstrating the importance of upper body strength in competitive swimming. These findings corroborate those of Negru [17], who reported significant negative relationships between 50m freestyle performance and various strength parameters. The negative correlation indicates that swimmers with greater grip strength achieved faster completion times, reflecting the critical role of upper body propulsive capacity.

Hand grip strength serves as a proxy indicator of overall upper body muscular strength and neuromuscular function [18]. In swimming, the upper body musculature generates the majority of propulsive force through repetitive pulling actions against water resistance. Enhanced grip strength may reflect greater development of the forearm, wrist, and hand musculature involved in effective hand positioning and water capture during the pull phase of all four strokes.

The predominance of left hand grip strength as the primary predictor (accounting for 60% of variance) presents an interesting finding. While the study did not assess hand dominance, this result may reflect several possibilities: (1) compensatory strength development in the non-dominant limb through training, (2) the importance of bilateral strength symmetry for optimal swimming mechanics, or (3) statistical variation within the sample. Future research should explicitly examine hand dominance and bilateral strength symmetry to clarify this relationship.

Geladas et al. [19] previously demonstrated positive associations between handgrip isometric strength and sprint swimming performance in young competitive swimmers. The present findings extend this evidence to the individual medley event, suggesting that upper body strength assessment may have broad applicability across swimming disciplines.

Flexibility and Swimming Performance

Shoulder flexibility demonstrated a moderate-to-strong negative correlation with swimming performance (r = -0.626), indicating that greater shoulder mobility was associated with faster completion times. This finding supports biomechanical principles suggesting that increased range of motion facilitates longer stroke length and greater propulsive efficiency [20].

The shoulder complex undergoes extensive range of motion during all four swimming strokes, particularly during the recovery and entry phases. Restricted shoulder mobility may limit stroke length, reduce propulsive effectiveness, and increase injury risk through compensatory movement patterns [21]. Krstić et al. [22] emphasized that while shoulder flexibility is important across all strokes, ankle and hip flexibility may be particularly critical for breaststroke performance.

Interestingly, despite its significant correlation, shoulder flexibility did not enter the regression model as an independent predictor when left hand grip strength was included. This may indicate: (1) shared variance between strength and flexibility measures, (2) the predominant importance of force production over range of motion in this sample, or (3) that flexibility contributes to performance primarily through its interaction with strength rather than as an independent factor.

Explosive Leg Strength and Swimming Performance

Lower limb explosive power showed a moderate negative correlation with swimming performance (r = -0.517). While this relationship was statistically significant, it was weaker than those observed for upper body strength and flexibility measures. This finding may reflect the varying contribution of leg propulsion across the four individual medley strokes.

Maglischo [12] noted that leg kick contributes approximately 60% of propulsion in breaststroke but plays a less dominant role in butterfly, backstroke, and freestyle. In the 200m individual medley, where each stroke comprises only 25% of the total distance, the overall contribution of leg power may be diluted compared to events dominated by breaststroke or where underwater kicking plays a more prominent role.

Nevertheless, explosive leg power remains functionally important for starts and turns, which constitute critical components of short-course swimming performance. Sadowski et al. [23] demonstrated that specific strength training targeting swimming-specific movement patterns

ISSN:1517-4492 | **E-ISSN**:2178-7727
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produced greater performance transfer than traditional resistance exercises. Future research might examine whether explosive power measured through more swimming-specific assessments (e.g., underwater kick velocity) demonstrates stronger performance relationships.

Practical Applications and Implications

The development of a predictive regression equation (R^2 = 0.60) has several practical applications for swimming coaches and sport scientists:

1. Talent Identification: Hand grip strength assessment provides a simple, time-efficient, and cost-effective screening tool for identifying swimmers with potential for success in individual medley events. This measure can be easily incorporated into talent identification batteries at regional and national levels.

2. Performance Monitoring: Regular assessment of grip strength can track training adaptations and identify periods of insufficient strength development. The regression equation allows coaches to set evidence-based performance targets and evaluate whether athletes are achieving expected improvements.

3. Training Program Design: The strong relationship between upper body strength and performance supports the inclusion of systematic strength training within comprehensive swimming programs. While swimming-specific training remains paramount, supplementary resistance training targeting grip, forearm, and upper body musculature may enhance performance outcomes.

4. Individualized Programming: The 40% of unexplained variance in the regression model highlights the multifactorial nature of swimming performance. Coaches should recognize that while strength is important, technical proficiency, race strategy, psychological factors, and other physiological attributes collectively determine competitive success.

Limitations and Future Research Directions

Several limitations warrant consideration when interpreting these findings:

1. Sample Characteristics: The study examined male swimmers from a specific geographic region with relatively homogeneous training backgrounds. Generalizability to female swimmers, elite international athletes, or different age groups requires verification through additional research.

2. Cross-Sectional Design: The correlational nature of this investigation precludes causal inferences. Longitudinal studies examining changes in bio-motor abilities and swimming performance over training cycles would strengthen evidence for causal relationships.

3. Limited Variable Set: The study examined four bio-motor variables. Future research should incorporate additional factors such as aerobic capacity, anaerobic threshold, stroke efficiency, anthropometric characteristics, and technical proficiency to develop more comprehensive predictive models.

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4. Measurement Specificity: While the bio-motor tests employed are validated and reliable, they represent general physical capacities rather than swimming-specific assessments. Future investigations might examine whether in-water strength and power measurements (e.g., tethered swimming force, stroke power) demonstrate stronger performance relationships.

5. Statistical Considerations: The relatively modest sample size (N = 40) limits statistical power for detecting smaller effects and restricts the number of predictors that can be reliably included in regression models. Larger samples would enable more sophisticated modeling approaches, including examination of non-linear relationships and interaction effects.

Future research directions include:

Examining sex differences in bio-motor ability-performance relationships
Investigating whether training interventions targeting identified bio-motor deficits enhance swimming performance
Developing stroke-specific predictive models that account for the unique demands of butterfly, backstroke, breaststroke, and freestyle
Incorporating technical and tactical variables alongside bio-motor measures in comprehensive performance models
Exploring the role of bilateral strength asymmetries in swimming performance and injury risk

Conclusions

This investigation provides empirical evidence for significant relationships between bio-motor abilities and 200m individual medley performance in competitive male swimmers. Key findings include:

Strong Performance Relationships: All examined bio-motor variables—bilateral hand grip strength, shoulder flexibility, and explosive leg strength—demonstrated significant negative correlations with swimming completion time, with correlation coefficients ranging from -0.517 to -0.774.

Primary Predictor Identified: Left hand grip strength emerged as the most significant predictor, independently accounting for 60% of performance variance. This finding highlights the critical importance of upper body strength in individual medley swimming.

Practical Predictive Model: A regression equation was developed that enables performance estimation based on a simple, accessible field test: Predicted Time (seconds) = 286.76 – 2.28 × (Left Hand Grip Strength in kg). This equation demonstrates practical utility for talent identification and performance monitoring.

Training Implications: The findings support the integration of systematic upper body strength development, particularly grip and forearm strengthening, within comprehensive swimming training programs. However, coaches should recognize that bio-motor abilities represent only one component of multifaceted swimming performance.

Foundation for Future Research: While hand grip strength proved to be a valuable predictor, the 40% of unexplained variance underscores the complex, multifactorial nature of swimming

ISSN:1517-4492 | **E-ISSN**:2178-7727
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performance. Future investigations should examine technical, physiological, and psychological factors alongside bio-motor abilities to develop more comprehensive performance models.

In summary, bio-motor ability assessment, particularly hand grip strength evaluation, offers valuable information for coaches, sport scientists, and athletes seeking to optimize individual medley performance. These findings provide evidence-based guidance for talent identification protocols and training program design in competitive swimming.

Acknowledgments
The authors express sincere gratitude to all swimming academies and clubs in Madhya Pradesh that facilitated participant recruitment and provided access to training facilities. We extend special appreciation to the athletes who volunteered their time and effort to participate in this investigation. Their commitment and enthusiasm made this research possible.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Ethical Approval: All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.

Conflict of Interest Statement
The authors declare no conflicts of interest related to this research. This study received no specific funding from commercial, public, or not-for-profit sectors.

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ISSN:1517-4492 | **E-ISSN**:2178-7727
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ISSN:1517-4492 | **E-ISSN**:2178-7727
Vol. 8, No. 1 (2025)