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REACTION TIME, MOVEMENT EFFICIENCY, AND FUNCTIONAL SYMMETRY CHARACTERISTICS OF ELITE FEMALE BOXERS ASSESSED USING THE QUICK BOARD SYSTEM

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ABOUT ARTICLE

Key words: neuromotor performance, Quick Board, reaction time, movement efficiency, functional asymmetry, elite female boxers, lower-limb symmetry, sensorimotor performance.

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Abstract: This study aimed to evaluate neuromotor performance, reaction time, movement efficiency, and lower-limb functional asymmetry in elite female boxers using the Quick Board assessment system. A total of nine elite female boxers participated in the study. Overall performance score, Foot Fire performance, left and right lower-limb reaction times, movement-efficiency scores, and functional symmetry indices were analyzed. The results demonstrated substantial inter-individual variability in neuromotor readiness, with total Quick Board scores ranging from 1207 to 3868 points. The highest overall performance was observed in S.T. (3868 points), whereas A.Ya. demonstrated the lowest score (1207 points). Mean reaction times were 0.819 ± 0.148 s and 0.811 ± 0.245 s for the left and right lower limbs, respectively. Functional symmetry analysis revealed clinically relevant asymmetries in several athletes, particularly F.F. (68.5%), N.O. (70.2%), and R.Q. (75.0%). Athletes with higher overall scores generally exhibited faster reaction times, greater movement efficiency, and superior bilateral symmetry. The findings indicate that Quick Board assessment provides a comprehensive evaluation of neuromotor readiness and may be effectively used for individualized training prescription, identification of functional deficits,

performance optimization, and injury-risk reduction in elite female boxing.

Introduction. Modern boxing is characterized by high-intensity intermittent actions that require rapid perception, decision-making, and execution of technically accurate movements under constantly changing competitive conditions. Competitive success depends not only on technical and tactical proficiency but also on neuromotor readiness, which determines the athlete's ability to react quickly and effectively to external stimuli (Chaabene et al., 2015; Loturco et al., 2019). In particular, reaction speed, movement efficiency, and lower-limb coordination are considered fundamental determinants of boxing performance because they directly influence footwork, defensive maneuvers, and counterattacking actions (Lenetsky et al., 2013; Beattie & Ruddock, 2022).

Recent advances in sports science have highlighted the importance of neuromotor assessment in monitoring athlete readiness and optimizing training processes. Neuromotor performance reflects the interaction between sensory perception, central nervous system processing, and motor execution, enabling athletes to perform complex sport-specific actions with high precision and speed (Bishop et al., 2018). Previous studies have demonstrated that superior reaction abilities and movement coordination are associated with improved agility, change-of-direction speed, and competitive performance across various combat sports (Slimani et al., 2017; Chaabene et al., 2018).

In boxing, lower-limb function plays a particularly important role because effective punching actions depend on the generation and transmission of force through the kinetic chain. According to Walilko et al. (2005), Piorkowski et al. (2011), and Lenetsky et al. (2015), successful punching performance requires coordinated activation of the lower limbs, pelvis, trunk, and upper extremities. Therefore, deficiencies in lower-limb reaction speed, movement efficiency, or bilateral coordination may negatively affect technical execution and overall sporting performance.

Functional asymmetry has also received considerable attention in sports biomechanics. Bishop et al. (2021) reported that substantial inter-limb asymmetries may impair movement efficiency, reduce athletic performance, and increase injury risk. Similarly, Maloney (2019) emphasized that asymmetrical neuromuscular function can influence balance control, force production, and change-of-direction performance. Consequently, the assessment of bilateral symmetry has become an important component of athlete monitoring programs.

The introduction of modern performance-analysis technologies has enabled more objective evaluation of neuromotor characteristics. Among these technologies, the Quick Board system provides comprehensive information regarding reaction time, movement efficiency, coordination accuracy, and functional symmetry. Previous investigations have demonstrated that Quick Board testing is a reliable method for assessing sport-specific neuromotor readiness and identifying individual strengths and weaknesses in elite athletes (Bishop et al., 2018; Loturco et al., 2019).

Although neuromotor performance has been widely investigated in various sports, limited information is available regarding the neuromotor profiles of elite female boxers. Furthermore, few studies have simultaneously examined overall Quick Board performance, reaction speed, movement efficiency, and lower-limb symmetry in high-performance female boxing athletes. This gap in the literature highlights the need for further research in this area.

Recent studies conducted in Uzbekistan have also emphasized the importance of neuromotor and biomechanical factors in boxing performance. Tajibayev, Umarov, and Abdullayev (2021) highlighted that the development of sport-pedagogical mastery in female boxing depends on the integrated improvement of technical, tactical, physical, and psychological preparedness. According to the authors, systematic monitoring of functional and coordination abilities plays an important role in optimizing long-term athlete development. Furthermore, Xalmuxamedov, Shin, Tajibayev, Rajabov, and Anashov (2020) emphasized that effective boxing performance is achieved through the coordinated development of motor abilities, technical skills, and movement control mechanisms. More recently, Tajibayev and Shomirzayev (2024) investigated the kinematic characteristics of the simple backstep movement in male and female boxers and demonstrated that lower-limb movement coordination and segmental interaction are essential components of technical efficiency. These findings further support the importance of assessing neuromotor performance characteristics, including reaction speed, movement efficiency, and functional symmetry, in elite boxing athletes.

Therefore, the purpose of this study was to evaluate neuromotor performance, reaction time, movement efficiency, and lower-limb functional asymmetry in elite female boxers using the Quick Board assessment system. It was hypothesized that substantial inter-individual differences would be observed despite the athletes competing at a similar elite level and that athletes with higher overall performance scores would demonstrate faster reaction times, greater movement efficiency, and superior bilateral symmetry.

Materials and Methods

Participants

Nine elite female boxers from the Uzbekistan Women's National Boxing Team voluntarily participated in this study. All athletes were actively preparing for national and international competitions and had extensive competitive experience at the elite level. Prior to participation, all athletes were informed about the purpose and procedures of the study and provided written informed consent. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki for research involving human participants.

Quick Board testing can be integrated into routine monitoring programs for elite female boxers to identify neuromotor deficits, evaluate functional asymmetries, guide individualized training interventions, and optimize competitive performance.

Study Design

A cross-sectional observational design was employed to evaluate neuromotor performance, reaction speed, movement efficiency, and lower-limb functional symmetry in elite female boxers. Testing was conducted under standardized laboratory conditions during the preparatory training period. Each athlete completed a comprehensive neuromotor assessment using the Quick Board system.

Instruments

Neuromotor performance was assessed using the **Quick Board™ reaction and movement analysis system** (Quick Board LLC, USA). The system is designed to evaluate sport-specific reaction time, foot speed, movement efficiency, coordination, and bilateral functional performance through multidirectional lower-limb movement tasks.

The following variables were recorded:

- Total Performance Score (points);
- Foot Fire Test (repetitions);
- Left Lower-Limb Reaction Time (s);
- Right Lower-Limb Reaction Time (s);
- Left Movement Efficiency Score;
- Right Movement Efficiency Score;
- Left Functional Symmetry (%);
- Right Functional Symmetry (%).

Testing Procedures

All athletes performed a standardized warm-up consisting of 10 min of low-intensity running, dynamic stretching, and sport-specific movement drills before testing. The Quick

Board assessment protocol was then administered according to the manufacturer's recommendations.

During testing, athletes responded to randomly illuminated targets on the Quick Board platform using rapid multidirectional foot movements. The system automatically calculated reaction time, movement efficiency, and symmetry indices based on the athlete's performance. Each participant completed the full testing protocol under identical conditions and was encouraged to perform at maximal effort.

Variables and Performance Indicators

Reaction time was defined as the elapsed time between stimulus presentation and the initiation of the appropriate lower-limb movement. Movement efficiency reflected the ability to perform rapid and accurate multidirectional actions with minimal unnecessary movement. Functional symmetry represented the relative balance of neuromuscular performance between the left and right lower limbs. Symmetry values below 85% were considered indicative of clinically relevant functional asymmetry (Bishop et al., 2021).

Statistical Analysis

Descriptive statistics were calculated for all variables and are presented as mean ± standard deviation (Mean ± SD), minimum values, and maximum values. Individual athlete profiles were analyzed to identify performance differences in reaction time, movement efficiency, and functional symmetry. Data processing and graphical visualization were performed using Microsoft Excel and statistical software packages.

The following descriptive statistical indicators were calculated:

[Mean \pm SD] [Minimum; Value] [Maximum; Value]

These analyses were used to characterize neuromotor performance profiles and identify potential functional asymmetries among elite female boxers.

Normality of data distribution was assessed using the Shapiro–Wilk test. Descriptive statistics are presented as mean ± standard deviation (SD), minimum and maximum values, and 95% confidence intervals (95% CI). Inter-limb effect sizes were calculated using Hedges' g and interpreted as trivial (<0.20), small (0.20–0.49), moderate (0.50–0.79), and large (≥0.80).

Results and Discussion. The descriptive statistics revealed substantial inter-individual variability in overall neuromotor performance among elite female boxers. Total Quick Board scores ranged from 1207 to 3868 points, with a mean value of 2376.6 ± 930.8 points. Foot Fire performance averaged 92.7 ± 9.5 repetitions, indicating a relatively high level of lower-limb movement frequency (Table 1).

Inter-limb comparisons demonstrated a trivial effect size for reaction time (g = 0.04), suggesting comparable neuromotor responsiveness between the left and right lower limbs. In contrast, movement efficiency exhibited a moderate effect favoring the right limb (g = -0.65), whereas functional symmetry showed a large effect size (g = -1.53), indicating substantially greater neuromuscular consistency in the right lower extremity. These findings suggest that bilateral differences were more pronounced in movement efficiency and functional symmetry than in reaction-time performance.

Table 1. Descriptive Statistics, 95% Confidence Intervals, and Effect Sizes of Neuromotor Performance Variables in Elite Female Boxers (n = 9)

Variable	Mean ± SD	95% CI	Min	Max	Hedges' g	Magnitude
Total Score (points)	2376.6 ± 930.8	1660.9–3092.3	1207	3868	–	–
Foot Fire (reps)	92.7 ± 9.5	85.4–100.0	81	109	–	–
Left RT (s)	0.819 ± 0.148	0.705–0.933	0.668	1.048	0.04†	Trivial
Right RT (s)	0.811 ± 0.245	0.623–0.999	0.610	1.257	–	–
Left Efficiency (score)	16.2 ± 6.1	11.5–20.9	9	25	-0.65†	Moderate
Right Efficiency (score)	19.8 ± 4.3	16.5–23.1	17	29	–	–
Left Symmetry (%)	85.6 ± 11.4	76.8–94.4	68.5	100.0	-1.53†	Large
Right Symmetry (%)	99.0 ± 2.9	96.8–101.2	91.2	100.0	–	–

Note. Data are expressed as mean ± SD, 95% CI, minimum, and maximum values. Hedges' g was used to quantify inter-limb effect sizes. RT = reaction time; CI = confidence interval; SD = standard deviation.

The relatively wide confidence intervals observed for Total Score and Left Symmetry indicate considerable variability among athletes, whereas Right Symmetry demonstrated the narrowest confidence interval, reflecting a more homogeneous performance profile across participants. Such findings support the use of individualized neuromotor monitoring for optimizing training interventions and identifying functional deficits in elite female boxing athletes.

Figure 1 presents the overall neuromotor performance scores of elite female boxers obtained using the Quick Board assessment system. Considerable inter-individual variability was observed among the athletes, with total scores ranging from 1207 to 3868 points. The mean group score was 2376.6 ± 930.8 points, indicating substantial differences in neuromotor readiness despite all athletes competing at a similar elite level.

The highest overall performance score was recorded by S.T. (3868 points), followed by F.K. (3211 points), F.F. (2833 points), and A.Z. (2803 points). In contrast, the lowest values were observed in A.Ya. (1207 points), N.O. (1500 points), O.S. (1673 points), and R.Q. (1676 points). The difference between the highest and lowest scores reached 2661 points, demonstrating pronounced variability in neuromotor performance within the sample.

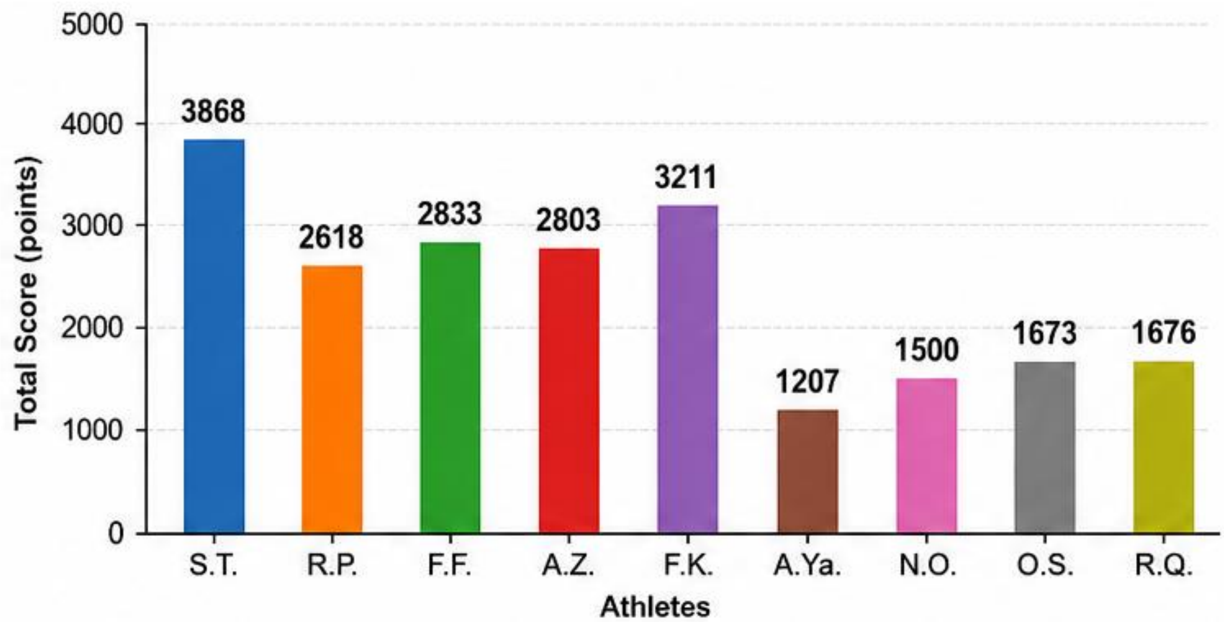

Figure 1. Overall Neuromotor Performance Scores of Elite Female Boxers Assessed by the Quick Board System.

The obtained results indicate that athletes with higher Quick Board scores demonstrated superior sensorimotor readiness characterized by faster reactions, more efficient lower-limb movements, and improved movement coordination. Conversely, athletes with lower scores exhibited reduced neuromotor efficiency and a lower capacity to perform rapid multidirectional actions.

From a biomechanical perspective, the total Quick Board score represents an integrated indicator of neuromuscular function, combining reaction speed, movement efficiency, coordination accuracy, and bilateral movement control. Therefore, higher scores may reflect a greater ability to execute boxing-specific actions such as footwork adjustments, defensive maneuvers, counterattacks, and rapid changes of direction.

The substantial variability observed among the athletes suggests that neuromotor readiness remains highly individualized even within elite female boxing. Similar observations have been reported by Bishop et al. (2018) and Loturco et al. (2019), who demonstrated that neuromuscular performance characteristics may differentiate athletes competing at comparable competitive levels. Furthermore, superior neuromotor performance has been associated with improved agility, movement efficiency, and sport-specific technical execution (Chaabene et al., 2018).

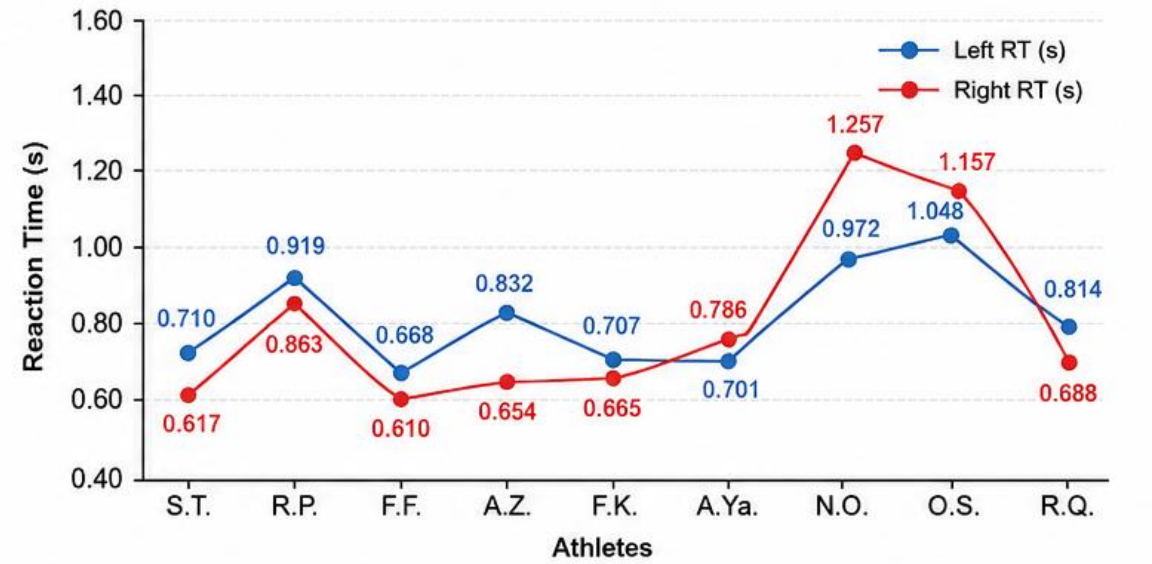

Figure 2. Left and right lower-limb reaction times of elite female boxers assessed using the Quick Board system.

Figure 2 illustrates the left and right lower-limb reaction times of elite female boxers assessed using the Quick Board system. The mean reaction time was 0.819 ± 0.148 s for the left lower limb and 0.811 ± 0.245 s for the right lower limb, indicating relatively similar reaction performance between limbs at the group level.

The fastest bilateral reaction times were recorded in F.F. (Left: 0.668 s; Right: 0.610 s), followed by F.K. (Left: 0.707 s; Right: 0.665 s) and S.T. (Left: 0.710 s; Right: 0.617 s). In contrast, the slowest reaction responses were observed in O.S. (Left: 1.048 s; Right: 1.157 s) and N.O.

(Left: 0.972 s; Right: 1.257 s). The difference between the fastest and slowest reaction times exceeded 0.64 s, demonstrating substantial variability in neuromotor responsiveness among the athletes.

Analysis of inter-limb differences revealed noticeable asymmetries in several participants. The greatest discrepancy was identified in N.O., whose right-leg reaction time exceeded the left-leg value by 0.285 s. Similarly, A.Z. demonstrated a difference of 0.178 s between limbs, whereas F.K. exhibited the most balanced reaction profile, with only a 0.042 s difference between the left and right lower limbs.

From a biomechanical perspective, reaction time reflects the efficiency of sensorimotor processing and the athlete’s ability to rapidly transform external stimuli into coordinated motor responses. Faster reaction times indicate superior neuromuscular responsiveness and may contribute to more effective footwork, defensive reactions, and counterattacking actions during competition. Conversely, slower reaction responses may limit the athlete’s ability to adapt to rapidly changing competitive situations.

The present findings are consistent with previous studies reporting that reaction speed is a key determinant of performance in combat sports. Chaabene et al. (2018) demonstrated that superior reaction abilities are associated with enhanced agility and sport-specific movement performance, while Loturco et al. (2019) identified neuromuscular responsiveness as an important characteristic distinguishing high-performing combat-sport athletes. The substantial variability observed in the current study further suggests that reaction-time characteristics remain highly individualized, even among elite female boxers.

Figure 3 presents the movement-efficiency scores of the left and right lower limbs in elite female boxers assessed using the Quick Board system. The mean movement-efficiency score was 16.2 ± 6.1 points for the left lower limb and 19.8 ± 4.3 points for the right lower limb, indicating generally greater movement efficiency in the right limb across the sample.

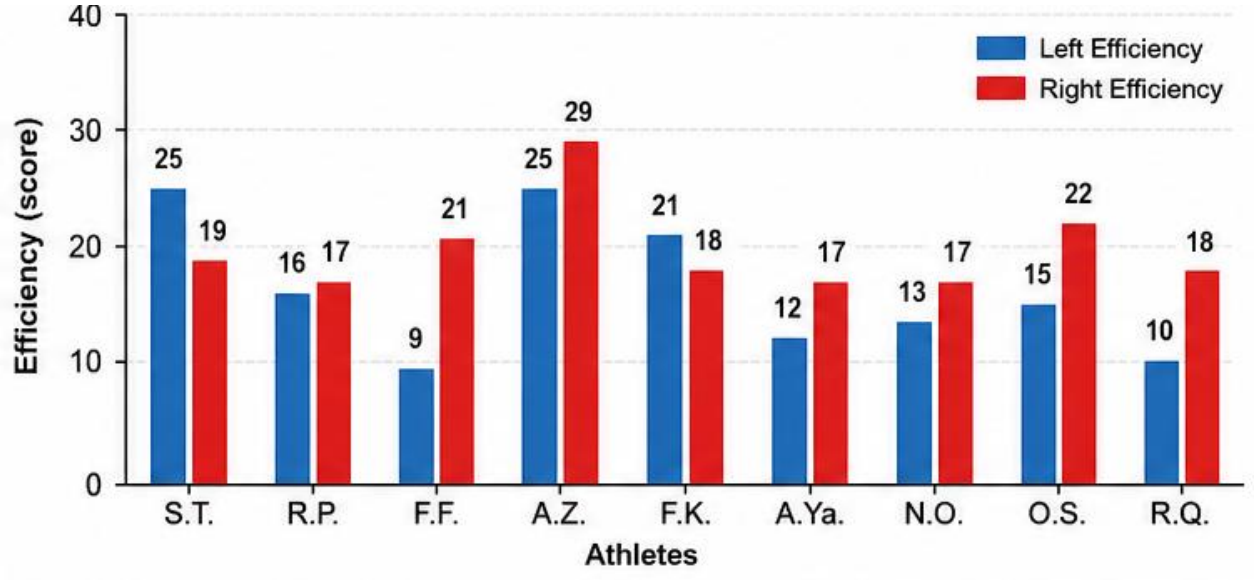

Figure 3. Left and right lower-limb movement efficiency scores of elite female boxers assessed using the Quick Board system.

The highest movement-efficiency values were recorded in A.Z. (Left: 25; Right: 29 points) and S.T. (Left: 25; Right: 19 points), demonstrating superior lower-limb coordination and neuromuscular control. Similarly, F.K. exhibited consistently high movement-efficiency scores (21 and 18 points), reflecting balanced and effective lower-limb function during multidirectional movement tasks. In contrast, the lowest left-limb efficiency score was observed in F.F. (9 points), whereas the lowest right-limb efficiency values were recorded in R.P. and A.Ya. (17 points).

Analysis of inter-limb differences revealed substantial variability among the athletes. The greatest asymmetry was identified in F.F., whose right-limb efficiency score exceeded the left-limb value by 12 points (21 vs. 9 points). Similarly, R.Q. demonstrated an 8-point difference (18 vs. 10 points), while O.S. exhibited a 7-point discrepancy (22 vs. 15 points). Conversely, R.P. showed the most balanced movement-efficiency profile, with only a 1-point difference between the left and right lower limbs (16 vs. 17 points).

From a biomechanical perspective, movement efficiency reflects the athlete's ability to perform rapid multidirectional movements while minimizing unnecessary motion and energy expenditure. Efficient movement patterns contribute to improved footwork, balance control, and positional adjustments, all of which are essential components of boxing performance. Athletes demonstrating higher movement-efficiency scores are therefore more likely to execute technical actions with greater precision and movement economy.

The predominance of right-limb efficiency observed in the present study may be explained by sport-specific adaptations associated with preferred stance and dominant-limb utilization. Similar findings have been reported in combat-sport athletes, where repeated unilateral movement patterns often lead to functional dominance of one lower extremity (Bishop et al., 2021). Furthermore, Beattie and Ruddock (2022) emphasized that efficient lower-limb movement is fundamental for effective force transmission, rapid repositioning, and technical performance in boxing.

The relationship observed between movement efficiency, reaction time, and overall Quick Board performance suggests that these variables represent interconnected components of neuromotor readiness. Athletes with superior movement-efficiency scores generally demonstrated faster reaction times and higher overall performance scores, indicating better sensorimotor integration and movement-control capabilities.

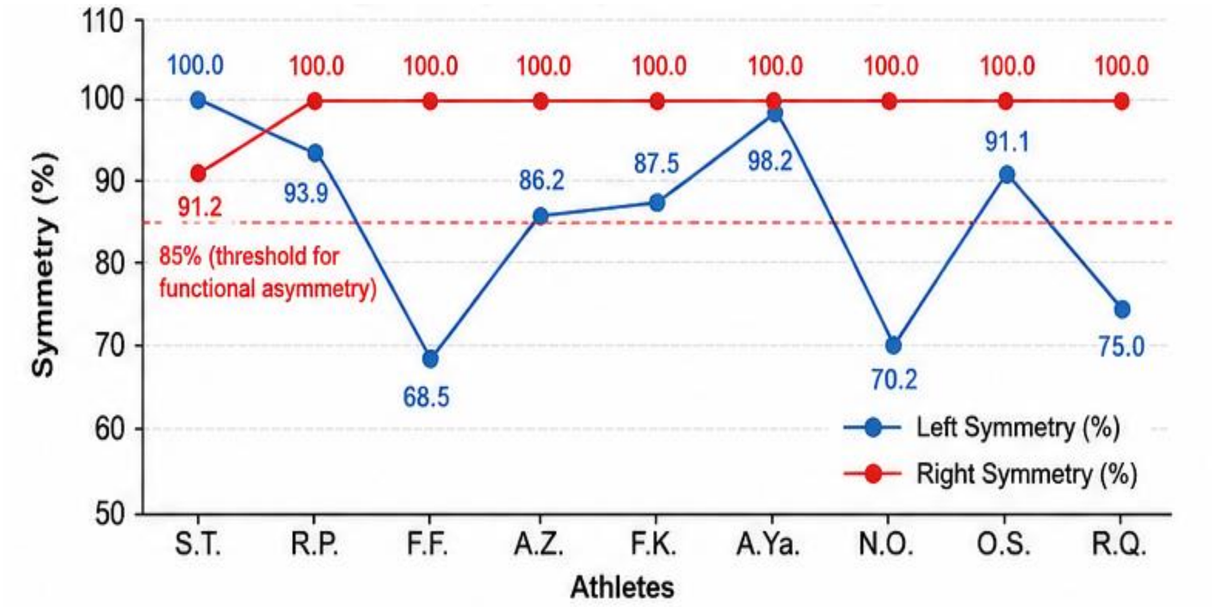

Figure 4. Left and right lower-limb functional symmetry profiles of elite female boxers.

Figure 4 illustrates the functional symmetry profiles of the left and right lower limbs in elite female boxers assessed using the Quick Board system. The mean left-limb symmetry was 85.6 ± 11.4%, whereas right-limb symmetry averaged 99.0 ± 2.9%, indicating substantially greater consistency and neuromuscular stability in the right lower limb across the sample.

Most athletes demonstrated right-limb symmetry values close to 100%, reflecting highly balanced neuromuscular function of the dominant lower extremity. However, considerable variability was observed in left-limb symmetry scores. Three athletes exhibited values below the commonly accepted 85% threshold for functional asymmetry. The lowest symmetry value was recorded in F.F. (68.5%), followed by N.O. (70.2%) and R.Q. (75.0%). These findings indicate substantial unilateral neuromuscular imbalance and suggest the presence of functional deficits that may negatively influence boxing-specific performance.

Moderate asymmetry was observed in A.Z. (86.2%) and F.K. (87.5%), whose values remained slightly above the threshold but below those observed in the most symmetrical athletes. In contrast, S.T. (100.0%), A.Ya. (98.2%), and R.P. (93.9%) demonstrated the most balanced symmetry profiles, indicating highly coordinated bilateral lower-limb function and efficient neuromuscular control.

The difference between the highest and lowest symmetry values reached 31.5 percentage points, highlighting substantial variability among athletes despite their similar competitive status. Furthermore, athletes presenting lower symmetry values generally demonstrated reduced movement-efficiency scores and lower overall Quick Board performance, suggesting a close relationship between functional symmetry and neuromotor readiness.

From a biomechanical perspective, functional symmetry reflects the ability of both lower limbs to generate and control movement in a balanced manner. Efficient bilateral coordination is essential for maintaining stability, executing rapid directional changes, and performing technically accurate boxing movements. Conversely, substantial asymmetries may result in inefficient force production, impaired balance control, and compensatory movement patterns that negatively affect performance.

These findings are consistent with previous research demonstrating that inter-limb asymmetries can reduce athletic performance and increase injury risk. Bishop et al. (2021) reported that asymmetrical neuromuscular function is associated with decreased movement efficiency and impaired physical performance, while Maloney (2019) highlighted the negative influence of bilateral deficits on agility, balance, and change-of-direction ability. The present results support these observations and demonstrate that clinically relevant asymmetries remain evident even among elite female boxers.

Conclusion. The present study evaluated neuromotor performance, reaction speed, movement efficiency, and lower-limb functional symmetry in elite female boxers using the Quick Board assessment system. The findings revealed substantial inter-individual variability across all measured variables, despite the athletes competing at a similarly high performance level. Total Quick Board scores ranged from 1207 to 3868 points, indicating considerable differences in neuromotor readiness and sensorimotor performance among the participants.

Reaction-time analysis demonstrated that athletes with higher overall performance scores generally exhibited faster neuromotor responses, suggesting a close relationship between reaction speed and boxing-specific performance capabilities. Furthermore, movement-efficiency assessment revealed that superior performers tended to display more efficient lower-limb movement patterns, highlighting the importance of coordinated and economical footwork during combat-sport activities.

Functional symmetry evaluation identified several athletes with clinically relevant inter-limb asymmetries (<85%), indicating potential neuromuscular imbalances that may negatively affect technical execution, movement quality, and injury risk. These findings emphasize the necessity of individualized corrective interventions targeting unilateral strength, proprioception, balance control, and neuromuscular coordination.

Overall, the results demonstrate that the Quick Board system provides a comprehensive and practical method for assessing neuromotor readiness in elite female boxing. The integration of reaction time, movement efficiency, and functional symmetry measures enables the identification of individual strengths and weaknesses that may not be detected through conventional performance testing. Therefore, regular neuromotor monitoring should be incorporated into elite boxing training programs to support evidence-based decision-making, optimize athlete development, improve competitive performance, and reduce the risk of injury.

These findings provide a scientific basis for implementing neuromotor monitoring systems in elite female boxing and support the use of Quick Board technology as a practical tool for evidence-based athlete management.

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