Bulletin of the *Transilvania* University of Braşov
Series IX: Sciences of Human Kinetics • Vol. 18(67) No. 2 – 2025
https://doi.org/10.31926/but.shk.2025.18.67.2.8

ANALYSIS OF THE RELATIONSHIP BETWEEN STATIC BALANCE PARAMETERS IN YOUNG BOXERS

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Abstract: *This study evaluated static balance in 11 young boxers (14–15 years) from the "Club Sportiv Iorgu" Association, using the Sensamove MiniBoard to assess performance and variability across balance axes. Mean overall performance was 71.73 %, with greater stability on frontal and right axes and instability on posterior and left axes (Back = –2.02, Left = –1.51). Performance variability was moderate on frontal axis (SD = 4.19) and lower on posterior and lateral axes (SD = 0.37–0.45). Coefficient of variation was low frontally (5.85 %) but higher laterally/posteriorly (up to 27.12 %). Correlation analysis showed a negative correlation between overall performance and frontal deviations (R = –0.654) and a positive correlation between frontal and posterior deviations (R = 0.669). It is necessary to use sport-specific training for improving posterior and lateral stability.*

Key words: *postural stability, deviations, performance, statistical analysis.*

1. Introduction

Balance is a key factor in athletic performance, particularly in boxing, where stability, coordination and postural control are essential for executing technical and tactical movements effectively [4], [13]. Static balance, the ability to maintain equilibrium in a stationary position, plays a crucial role in a boxer's defensive and offensive strategies, reaction time and overall performance [6].

Young boxers, in their developmental phase, need enhanced neuromuscular control to maintain proper postural alignment and stability during training and competition [7]. Balance proficiency is influenced by multiple factors, including core strength, proprioceptive feedback and foot positioning [8]. Research highlights differences between expert and novice combat athletes in maintaining balance [9] and emphasizes the role of visualization in postural stability [14]. Additionally, functional strength training has been shown to improve both offensive and defensive performance by enhancing postural control [1].

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Understanding the relationship between different static balance parameters provides important data about training methodologies that optimize performance and reduce injury risks [2]. Studies have explored the impact of core exercises on balance and physical performance in young boxers [5] and the influence of foot measures on balance in children engaged in different sports [8]. Furthermore, postural control varies depending on training scenarios, such as shadow boxing versus bag training [2], while visual attention and eye-hand coordination also contribute significantly to balance maintenance in boxing [3].

To deepen the understanding of the underlying mechanisms, it is essential to assess static balance using objective tools that precisely quantify postural sway and body-weight distribution. Moreover, correlating these parameters with training level and anthropometric factors can provide important insights for tailoring individualized conditioning programs. Identifying weaknesses in postural control can therefore guide specific interventions aimed at injury prevention and performance enhancement. Recent studies confirm that sport-specific fatigue can alter dynamic postural stability in elite junior boxers [10], while anthropometric indices and body composition strongly influence postural stability in martial arts athletes [16]. Similarly, comparisons of static and dynamic core exercises demonstrate significant improvements in balance and physical performance in young boxers [5].

In addition, understanding how directional balance control differs across anterior–posterior and medial–lateral planes may clarify the specific neuromuscular demands imposed by boxing footwork and defensive maneuvers. Integrating longitudinal monitoring of balance parameters throughout a training season could reveal adaptation patterns and highlight critical periods for targeted intervention. Finally, linking balance outcomes with competition performance metrics—such as punch accuracy or defensive efficiency—would strengthen the practical relevance of balance assessment for both coaches and athletes.

This study aims to analyze the correlation between various static balance parameters in young boxers. By examining factors such as postural sway, weight distribution and stability indices, the study tries to identify key determinants of balance mastery and recommend targeted training interventions to enhance stability and coordination.

2. Methods

The research was conducted in January 2025 with a descriptive aim in data analysis. The study was carried out within the “Club Sportiv Iorgu” Association in Bucharest and involved 11 athletes aged between 14 and 15 years.

For assessing static balance, the Sensamove MiniBoard was used, in collaboration with the Human Performance Research Center (University Center in Pitești). The parameters analyzed included overall performance (%) and mean deviations in the anterior, posterior, left lateral and right lateral directions.

Statistical analysis was performed by means of the KyPlot program, using descriptive indices and the Pearson correlation coefficient.

3. Results

To determine the relationship between static balance indices in young boxers, a descriptive analysis (Table 1) and a correlational analysis (Pearson's R) were conducted, highlighting the relationships between performance on different balance axes (front, back, left and right).

Descriptive analysis of the static balance parameters Table 1

Statistical indicators	Perf. (%)	Front, avg. dev. (degrees)	Back, avg, dev. (degrees)	Left, avg. dev. (degrees)	Right, avg. dev. (degrees)
mean	71.73	1.78	-2.02	-1.51	1.65
SD	4.19	0.47	0.45	0.41	0.37
Cv(%)	5.85	26.26	22.05	27.12	22.55
Confidence Level of Mean (0.95)	2.82	0.31	0.29	0.27	0.25

The descriptive statistics presented in Table 1 provide a detailed profile of static balance performance in young boxers.

The overall stability score averaged 71.73 %, indicating a generally good ability to maintain balance during the test. Mean deviations show a forward (1.78°) and rightward (1.65°) bias, while the negative mean values for the backward (–2.02°) and leftward (–1.51°) directions reflect a tendency toward instability in the posterior–lateral quadrants. This directional asymmetry suggests that athletes compensate more effectively in the anterior and right planes, whereas control in the posterior and left planes is weaker.

Regarding variability, the standard deviation (SD) for overall performance on the frontal axis was 4.19, a moderate dispersion consistent with the relatively low coefficient of variation (CV = 5.85 %), indicating stable forward–back control in the participants.

In contrast, the posterior and lateral deviations had smaller SD values (0.37–0.45) but markedly higher CVs (22–27 %), meaning that although the absolute range of deviation was limited, the relative variability was substantial.

This pattern reveals heterogeneity among athletes in controlling subtle shifts backward and laterally, pointing to individual differences in neuromuscular strategies or proprioceptive feedback.

The 95 % confidence intervals further support these findings, with narrow ranges for each direction (e.g., ±0.25–0.31°). This fact underscores the measurements precision and reinforces the reliability of the observed asymmetries.

Taken together, the data prove that while the group maintains satisfactory overall static balance, targeted interventions should prioritize posterior and left-lateral stability training. This is necessary to reduce inter-individual variability and enhance symmetrical postural control—factors critical for optimizing boxing-specific performance and reducing injury risk.

The correlational analysis presented in Table 2 and Figure 1 offers a more comprehensive understanding of the interrelationships among the static balance parameters in young boxers.

Table 2

Correlational analysis between the static balance indices

R, Pearson	Perf. (%)	Front, avg. dev. (deg.)	Back, avg, dev. (deg.)	Left, avg. dev. (deg.)	Right, avg. dev. (deg.)
Front, avg. dev. (degrees)	-0.654*	-			
Back, avg, dev. (degrees)	0.669*	-0.377	-		
Left, avg. dev. (degrees)	0.312	0.0002	-0.293	-	
Right, avg. Dev. (degrees)	-0.566	0.099	-0.398	0.023	-

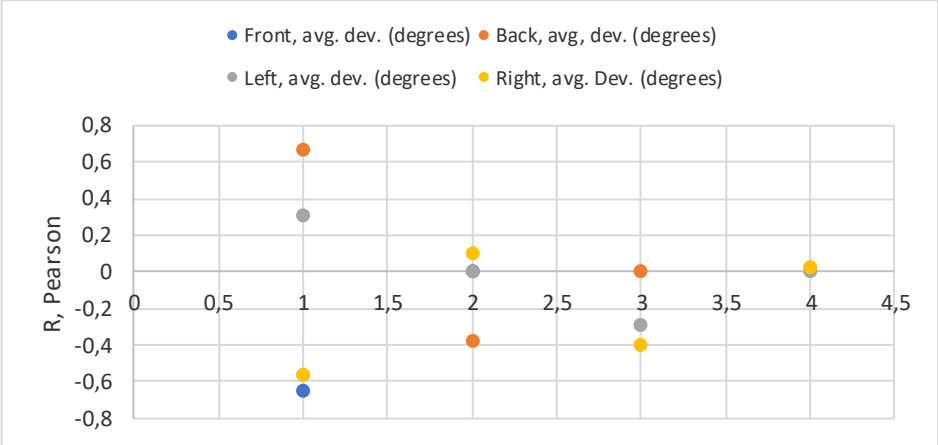

Fig. 1. *Correlational analysis between the static balance indices*

Overall performance vs. frontal deviation: The significant negative correlation ($R = –0.654$, $p < 0.05$) indicates that athletes who had greater sway along the frontal (antero-posterior) axis achieved lower overall balance performance. This suggests that excessive forward–backward oscillation is a key limiting factor in postural control, potentially reflecting insufficient core stability or delayed neuromuscular feedback.

Frontal vs. posterior deviation: The positive association ($R = 0.669$, $p < 0.05$) shows that increased motion on the frontal axis was accompanied by similar displacements on the posterior axis, highlighting a coupled sway pattern. Such coupling may result from compensatory strategies, where anterior instability provokes a backward countermovement to maintain balance.

Lateral deviations: Correlations involving left and right deviations were weak and nonsignificant, reflecting that lateral sway was largely independent of antero-posterior control. This independence underscores that training interventions should specifically target sagittal-plane stability without expecting automatic

transfer to lateral stability.

Findings show that conditioning programs are needed to strengthen core musculature and improve proprioceptive control for limiting forward–backward sway and enhancing overall static balance.

4. Discussion

The results emphasize superior postural stability on the frontal and right axes, with more pronounced instability on the posterior and lateral axes, as shown by the negative mean values for the "Back" and "Left" deviations. This distribution indicates a better ability to control balance in the forward and right directions, while the increased instability on the posterior and lateral axes may signal deficiencies in the compensatory mechanisms and balance regulation strategies [16]. The reduced variability on the frontal axis and the significant coefficient of variation on the lateral and posterior axes confirm more consistent performance in maintaining balance forward, but a higher susceptibility to perturbations in other directions.

Boxing training is well known to improve balance, postural control and proprioception, with core stability identified as a key factor for efficient neuromuscular regulation [5]. However, sport-specific fatigue can negatively affect dynamic balance, which may partially explain the directional differences observed [10]. Boxers have been reported to exhibit superior static balance compared with athletes from other sports, supporting the idea that repeated exposure to rapid directional changes fosters enhanced postural control [8], [9]. Kinesiology taping has also been shown to be benefic to neuromuscular control and stability, providing a potential adjunct to training [15]. Furthermore, boxing-based interventions can aid rehabilitation by improving balance and gait, even in clinical populations [11].

The correlational results show that higher overall performance is associated with reduced deviations on the frontal axis, demonstrating more efficient postural control in this direction. The important positive relationship between frontal and posterior deviations reveals interdependence in balance regulation mechanisms, which may reflect common postural stabilization strategies or compensatory adaptations [4]. Similar inter-plane relationships between static and dynamic balance have been reported in young athletes, supporting the need for integrated assessments [13].

The specialized literature reinforces these findings. Greater knee extensor strength has correlated with higher punch impact forces, suggesting that lower-limb power contributes both to striking and to stable stance [17]. Gait asymmetries have also been associated with performance decrements and increased injury risk in professional boxers, underscoring the importance of symmetrical postural control [12].

Moreover, the directional pattern observed - stronger control forward and to the right - may reflect sport-specific demands, as offensive actions in boxing often emphasize forward weight transfer and dominant-hand engagement [2]. Growth-related changes in limb length and center-of-mass distribution during adolescence could further accentuate these asymmetries, making longitudinal monitoring particularly relevant for youth athletes [7].

Integrating multidirectional balance

drills, single-leg strength exercises and real-time biofeedback into training could therefore address the weaker posterior and lateral control while supporting injury prevention [3], [14]. Future studies should examine how these targeted interventions influence neuromuscular adaptations and long-term competitive performance.

Recommendations – Future Directions:

1. Axis-specific balance training – Implement targeted stability drills for posterior and lateral planes, including unstable-surface work, vision-restricted tasks and rapid trunk-rotation exercises.
2. Lower-limb explosive strength development – Incorporate plyometric and knee–hip strength programs to reinforce postural control and punching power.
3. Sport-specific fatigue monitoring – Use periodic static and dynamic balance assessments to adjust training load and reduce fatigue-related stability loss.
4. Correction of functional asymmetries – Conduct regular gait and posture analyses to detect left–right imbalances and integrate corrective strength and mobility work.
5. Neuromuscular & proprioceptive enhancement – Apply neurofeedback drills, kinesiology taping and eyes-closed balance exercises to refine sensory feedback and neuromuscular adaptation.

These recommendations complement the discussion on the results and can guide both practical interventions and future research aimed at optimizing performance and reducing injury risk in young boxers.

5. Conclusion

Boxing training enhances postural control, particularly in the anterior and rightward directions, but shows increased instability in the posterior and lateral axes, suggesting the need for targeted interventions to address balance deficits in these areas.

The correlation between reduced deviations on the frontal axis and better overall performance highlights the importance of effective postural regulation in maintaining stability during boxing movements, with interdependence between frontal and posterior balance mechanisms.

To optimize performance and reduce the risk of injuries, boxing training should integrate exercises that focus on dynamic balance, explosive strength and correction of limb asymmetries, as sport-specific fatigue and gait asymmetries can negatively affect balance and performance.

These findings underscore the need for a multidimensional approach to boxer preparation, in which systematic balance assessment is combined with individualized neuromuscular and strength training, ensuring long-term improvements in stability, performance and injury resilience.

Acknowledgements

This study is part of the doctoral research within the Institute of Physical Education and Sports of the State University of Moldova. We would like to thank the management of the Sports Association, the coaches and athletes who participated in the research.

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