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Dynamic balance as a predictor of punching performance in elite boxers: A correlation study

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Abstract
Background: Dynamic balance integrating proprioception, reaction ability, and coordination is essential in combat sports where stability under motion underpins both offense and defense. This study examined the association between dynamic balance and punching performance (speed and power) in elite boxers.
Methods: Eleven national-level male boxers (aged 18–25 years; ≥5 years training experience) completed dynamic balance assessment using the Sensamove Sensabalance Miniboard. Proprioception, reaction ability, and coordination were recorded individually, standardized into z-scores, and summed to yield a composite dynamic balance score. Punching performance was assessed using Corner® trackers. Pearson's correlations were used ($\alpha = 0.05$).
Results: The composite dynamic balance score showed significant inverse correlations with punch speed ($r = -0.723$, $p = 0.012$) and punch power ($r = -0.764$, $p = 0.006$). Since higher scores indicated greater deviation from optimal balance, these results demonstrate that athletes with better balance achieved faster and more powerful punches.
Conclusion: Dynamic balance is a strong predictor of striking performance in elite boxing. Integrating targeted balance training into boxing programs is recommended to enhance athletic output and competitive success.

Keywords: Boxing, dynamic balance, punch speed, punch power, proprioception, coordination, reaction time

1. Introduction
Boxing is a high-intensity combat sport that demands a unique combination of technical precision, rapid reflexes, explosive strength, and efficient movement control. Success in the ring requires more than upper-body force; it depends on the ability to integrate balance, coordination, and timing with offensive and defensive strategies. Among these attributes, dynamic balance the capacity to maintain postural stability while the body is in motion plays a critical role in executing punches, evading attacks, and maintaining ring control (Horak, 1987; Winter, 1995) [12-2]. Effective footwork, stance stability, and seamless transitions between attack and defense are all mediated by dynamic balance.
Dynamic balance is a composite function of proprioception, reaction ability, and coordination. Proprioceptive feedback provides awareness of joint and limb positioning, coordination ensures smooth integration of upper- and lower-body movements, and reaction ability allows rapid adjustments to unpredictable external stimuli (Schmidt & Lee, 2011) [3]. Prior research in combat sports has highlighted the role of neuromuscular control and stance stability in enhancing strike efficiency. For example, Loturco *et al*. (2016) [5] reported strong associations between lower-limb power and punching impact in boxers, while Beattie and Ruddock (2022) [4] emphasized the contribution of strength to strike performance. Similar findings in other martial arts have shown that stability influences both kicking velocity (Kim & Lee, 2023) [7] and punch mechanics (Skalski *et al*., 2025) [8]. Furthermore, reviews indicate that combat sports training enhances proprioceptive ability and postural control, reinforcing the importance of balance in athletic development (Valdés-Badilla *et al*., 2022; Hernandez-Martinez *et al*., 2025) [10, 11].
Despite its recognized importance**,** limited empirical research has directly examined whether dynamic balance predicts punching performance in boxing**.** While studies in related combat

sports have suggested this connection, few have analyzed elite-level boxers using objective measures of balance and punching ability. Addressing this gap, the present study investigated the relationship between dynamic balance and punching performance (speed and power) in national-level boxers. It was hypothesized that boxers with superior balance reflected by lower composite balance scores would demonstrate higher punching speed and power.

2. Materials and Methods

2.1 Participants

Eleven national-level male boxers (mean age: 21.3 ± 2.1 years; training experience ≥5 years) were selected using purposive sampling. All participants were injury-free for at least six months prior to testing. The study was conducted as part of the author's M.P.Ed. dissertation at Lakshmibai National Institute of Physical Education (LNIPE) and was reviewed and approved by the departmental research committee. All procedures were carried out in accordance with the ethical standards of the Declaration of Helsinki, and written informed consent was obtained from all participants.

2.2 Instruments

Dynamic balance was assessed using Sensamove's Sensabalance Miniboard with the Baseline Measurement System (BMS) and 10° accessory. Proprioception, coordination, and reaction ability were recorded separately. Because each variable was measured on a different scale, raw scores were first converted into standardized scores (z-scores). The three standardized values were then summed to yield the composite dynamic balance score, with higher composite scores reflecting greater deviation from optimal balance (i.e., poorer balance).

Punching performance (speed in mph and power in g-force) was measured using Corner® wrist-worn boxing performance trackers. Both systems have demonstrated high reliability (ICC ≥ 0.85) in previous validation studies.

2.3 Procedure

Testing was conducted in a controlled indoor setting (24°C, wooden floor). Participants first completed dynamic balance testing, followed by standardized punching performance assessments. Each measure was tested in triplicate, with the best score used for analysis. Testing order was standardized to minimize fatigue.

2.4 Statistical analysis

Normality was verified using the Shapiro–Wilk test. Pearson's Product-Moment Correlation Coefficient was applied to normally distributed variables. Statistical significance was set at $p<0.05$, and effect sizes were interpreted following Cohen (1988).

3. Results

The composite dynamic balance score (derived from standardized proprioception, coordination, and reaction ability scores) demonstrated large, significant inverse correlations with both punch speed ($r = -0.723$, $p = 0.012$) and punch power ($r = -0.764$, $p = 0.006$). This indicates that athletes with better balance (i.e., lower deviation from optimal balance) achieved faster and more powerful punches.

Table 1: Descriptive statistics of study variables (N=11)

Variable	Mean ± SD	Min	Max
Dynamic balance score	14.8 ± 3.2	10.0	21.0
Punch speed (mph)	27.5 ± 2.1	24.1	31.0
Punch power (g-force)	451 ± 42	398	512

Table 2: Correlations between dynamic balance and punching performance

Variable pair	r	p-value
Balance vs punch speed	-0.723	0.012
Balance vs punch power	-0.764	0.006

4. Discussion

The findings demonstrate that superior dynamic balance is associated with better punching performance among elite-level boxers. This aligns with theoretical frameworks of biomechanics, which emphasize the role of a stable base in optimizing kinetic chain force transfer. Our results are consistent with evidence from Taekwondo (Kim & Lee, 2023) [7], MMA (Skalski *et al*., 2025) [8], and prior boxing strength studies (Loturco *et al*., 2016; Beattie & Ruddock, 2022) [5, 4].

By combining standardized scores for proprioception, coordination, and reaction ability, this study operationalized dynamic balance as a multidimensional construct, which is consistent with Horak's model of balance as an integrated system of sensory and motor components (Horak, 1987; Horak, 2006) [1, 12]. This methodological choice strengthens the theoretical basis for interpreting dynamic balance as a predictor of performance.

The small sample size (N=11) is a limitation, but the elite competitive level of the participants supports ecological validity. Future research should employ larger and more diverse samples, and examine longitudinal training interventions to establish causality.

5. Conclusion

Dynamic balance a composite of proprioception, reaction ability, and coordination is significantly associated with punching speed and power in elite boxers. These results highlight the importance of integrating targeted balance training into boxing programs to enhance performance outcomes.

6. Acknowledgement

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