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# The Impact of Strength Training With Ballistic Stretches in The Development of Some Forms of Flexibility and Range of Motion in Young Boxing Players

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**ABSTRACT**
Backgroud: To evaluate the impact of an eight-week conditioning program combining muscular strength exercises with ballistic stretching on spinal flexibility, hip flexibility, and active arm range of motion in adolescent competitive boxers.
Methods: Using a single-group pretest-posttest quasi-experimental design, 12 competitive male adolescent boxers (mean age 15.42 ± 0.67 years) from Al-Muwaffaqiyah Boxing Club completed 24 supervised conditioning sessions across eight weeks (three 45-minute sessions weekly). Outcome measures comprised backward trunk hyperextension for spinal flexibility (cm), standing forward trunk flexion on an elevated test box for hip flexibility (cm), and active shoulder extension-elevation measured with a 360-degree goniometer (degrees). Statistical evaluation included paired Student's t-tests with exact degrees of freedom (df = 11), 95% confidence intervals of mean differences, and effect size calculations (Cohen's d_z and Hedges' g).
Results: Post-intervention tests revealed statistically significant increases across all three physical parameters ($p < 0.001$). Spinal flexibility expanded from 79.17 ± 2.14 cm to 87.50 ± 1.87 cm, yielding a mean difference of +8.33 cm (95% CI [6.65, 10.02], $t(11) = 10.86$, Cohen's d_z = 3.14, Hedges' g = 4.01). Hip joint flexibility improved from 19.72 ± 1.64 cm to 26.92 ± 1.38 cm, reflecting a mean difference of +7.20 cm (95% CI [5.74, 8.66], $t(11) = 10.85$, Cohen's d_z = 3.13, Hedges' g = 4.60). Active arm range of motion increased by +15.45° (from 188.98 ± 2.08° to 204.43 ± 7.00°, 95% CI [11.05, 19.85], $t(11) = 7.73$, Cohen's d_z = 2.23, Hedges' g = 2.89).
Conclusions: Pairing targeted muscular strength work directly with ballistic stretching generates notable improvements in dynamic spinal, hip, and shoulder mobility among adolescent boxers. These structural adaptations stem from viscoelastic stress relaxation in musculotendinous tissues and modulated myotatic reflex responsiveness. This integration provides young combat athletes with mechanical advantages for trunk rotation, defensive slipping, and punching reach without causing structural overload.

**Keywords:** Adolescent boxers; Ballistic stretching; Dynamic flexibility; Joint range of motion; Musculotendinous stiffness.

## INTRODUCTION

Competitive amateur boxing demands rapid force generation, agile footwork, and fluid multi-planar trunk movement within strict time constraints (Chaabene et al., 2018; Franchini et al., 2019). During competitive bouts, boxers continuously alternate between explosive attacking combinations and rapid evasive maneuvers such as slips, ducks, and bob-and-weave patterns. Executing these actions efficiently requires optimal coordination across the entire

musculoskeletal system. Physical preparation in boxing has historically centered on building aerobic capacity, anaerobic endurance, and raw punching strength (Turner et al., 2016). Yet without adequate dynamic mobility, high levels of muscle tension can restrict joint motion, reduce movement efficiency, and elevate mechanical strain during high-velocity impacts (McHugh & Cosgrave, 2010; Suchomel et al., 2018). Dynamic joint mobility, specifically along the spine, hips, and shoulder girdles, forms the mechanical foundation through which punching velocity and defensive agility are expressed.

From a biomechanical standpoint, punching is not an isolated upper-body action; it operates through a kinetic chain originating from ground reaction forces (Lenetsky et al., 2020). Force begins with ankle plant and knee extension, transfers through pelvic rotation and lumbar hyperextension/rotation, and culminates in scapulothoracic projection and glenohumeral extension. Studies examining combat biomechanics confirm that trunk rotation contributes up to 40% of the total force delivered in straight punches and hooks (Lenetsky et al., 2020; Turner et al., 2016). When a boxer exhibits restricted spinal flexibility or limited hip excursion, rotational acceleration is arrested prematurely. The athlete is then forced to compensate by over-activating shoulder and arm musculature. This compensatory pattern decreases punching velocity, reduces punch reach, and increases joint stress across the glenohumeral complex.

To expand joint excursion while preserving muscular power, sports scientists have increasingly turned to ballistic stretching (Behm & Chaouachi, 2011; Thomas et al., 2018). Ballistic stretching involves repetitive, bouncing, or bobbing movements where terminal momentum drives the limb past its typical active boundary. This dynamic mode differs fundamentally from static stretching, which frequently induces a temporary loss of muscle stiffness and neural drive, known as the stretch-induced force deficit (Behm et al., 2016; Chaabene et al., 2019). The neurophysiological mechanism governing ballistic stretching centers on the muscle spindle and the myotatic or stretch reflex loop (Blazevich et al., 2014; Opplert & Babault, 2018). Muscle spindles, innervated by primary Ia sensory afferents, detect both the rate and magnitude of muscle lengthening. Under sudden dynamic loading, these receptors trigger a protective reflex contraction to prevent overextension. Systematic exposure to controlled ballistic movements progressively recalibrates gamma motor neuron dynamic sensitivity (Konrad et al., 2021). Over time, this modification raises the threshold of the myotatic reflex, permitting greater dynamic displacement before protective tension is initiated (Weppler & Magnusson, 2010; Zhou et al., 2023). Simultaneously, repeated cycles of tension and relaxation promote viscoelastic stress relaxation in connective tissues, decreasing passive stiffness within the series elastic component without suppressing contractile power output.

Prescribing dynamic ballistic protocols for adolescent athletes requires careful mechanical modulation. During puberty, rapid longitudinal bone growth often outpaces the lengthening of corresponding muscle-tendon units, creating temporary flexibility deficits and heightened tendon tension. Executing uncontrolled ballistic actions with excessive momentum introduces potential risks of connective tissue microtrauma or muscle strain in developing adolescents (Dunn et al., 2022). Consequently, pairing ballistic stretching directly with targeted muscular strength training provides a protective mechanical counterbalance (Afonso et al., 2021; Suchomel et al., 2018). Strengthening exercises build active joint stability and tendon tolerance, while paired ballistic movements preserve compliance and dynamic range. This combination helps youth boxers adapt safely to the violent decelerations and rapid directional changes inherent to ring competition.

Prior research in combat sports has evaluated isolated static stretching or generic conditioning programs (Franchini et al., 2019; Thomas et al., 2018), but structured data detailing how integrated strength work and ballistic stretching modify joint mobility in adolescent boxers remains scarce (Turner et al., 2016; Zhou et al., 2023). Earlier local studies occasionally suffered from conceptual ambiguity, claiming to evaluate complex ring combat tactics while only measuring physical flexibility. To establish methodological clarity, the current investigation isolates physical and functional mobility outcomes, setting aside tactical scoring metrics. Specifically, this study evaluates the impact of an eight-week conditioning program combining

muscular strength exercises with ballistic stretching on three primary variables: spinal flexibility, hip joint flexibility, and active arm range of motion in competitive adolescent boxers. We hypothesized that participants completing the eight-week intervention would demonstrate statistically significant improvements across all three flexibility parameters compared to baseline levels.

## METHODS

### Research Design and Methodological Considerations

This study employed a single-group pretest-posttest quasi-experimental design (O1 -> X -> O2) to assess functional flexibility adaptations following an eight-week physical conditioning intervention. Quasi-experimental single-cohort designs are frequently used in elite athletic academies where the available participant pool is inherently small and dividing competitive athletes into non-training control groups raises practical and ethical concerns (Franchini et al., 2019; Turner et al., 2016). The lack of an independent, parallel control group represents a clear methodological limitation that must be acknowledged openly. Without an active comparison group, natural biological maturation and secondary background training cannot be fully isolated through statistical subtraction. Nevertheless, this design was selected because withholding targeted physical conditioning from a subset of registered youth boxers during a competitive preparation cycle was unacceptable to coaching staff, and the total regional pool of licensed adolescent boxers was strictly limited.

### Participants and Sampling Frame

The target population included all registered adolescent male boxers active within sports clubs in the Wasit Governorate boxing league. The regional directory listed 50 competitive youth boxers distributed across four affiliated clubs: Al-Muwaffaqiyah Sports Club (n = 15), Al-Kut Sports Club (n = 14), Damoc Sports Club (n = 11), and Al-Nu'maniyah Sports Club (n = 10), as summarized in Table 1. Al-Muwaffaqiyah Sports Club was selected as the experimental site through purposeful institutional selection, given its dedicated boxing training facilities and full compliance with the study timeline.

**Table 1. Distribution of Registered Adolescent Boxers Across Wasit Governorate Clubs**

| Club Name | Registered Boxers (n) | Percentage of Regional Population (%) |
|---|---|---|
| Al-Muwaffaqiyah Sports Club | 15 | 30.0% |
| Al-Kut Sports Club | 14 | 28.0% |
| Damoc Sports Club | 11 | 22.0% |
| Al-Nu'maniyah Sports Club | 10 | 20.0% |

Of the 15 registered boxers at Al-Muwaffaqiyah Sports Club, three athletes were randomly assigned to the preliminary pilot study to calibrate test procedures and establish test-retest reliability. The remaining 12 boxers formed the definitive experimental cohort (N = 12), representing 24.0% of the total regional boxing population. Inclusion criteria required participants to: (a) hold active competitive registration in the youth boxing division, (b) possess a chronological age between 15 and 16 years, (c) have completed at least two consecutive years of structured boxing training, and (d) possess medical clearance confirming zero musculoskeletal injuries in the six months preceding the study. Baseline descriptive characteristics for the experimental cohort were: age = 15.42 ± 0.67 years, stature = 168.5 ± 5.2 cm, body mass = 58.3 ± 4.6 kg, and competitive training background = 2.8 ± 0.7 years. Written informed consent was secured from parents or legal guardians, and institutional ethical approval was granted by the Sports Science Committee at the Wasit Education Directorate.

### Chronological Timeline and Field Procedures

All experimental procedures followed a strict chronological sequence during the 2026 athletic calendar to eliminate temporal ambiguity (Clemente et al., 2021; Loturco et al., 2021). The preliminary pilot testing was completed on Friday, July 10, 2026, using the three designated

pilot boxers. A second test session was conducted on Friday, July 17, 2026, under identical environmental conditions to establish test-retest reliability coefficients. Pre-intervention baseline testing for the primary cohort (N = 12) took place on Sunday, July 19, 2026, between 16:00 and 18:00 at the Al-Muwaffaqiyah Sports Club Gymnasium. The eight-week conditioning program ran from Monday, July 20, 2026, through Sunday, September 20, 2026, comprising 24 total training sessions. Post-intervention testing was executed on Wednesday, September 23, 2026, at 17:00 at the Al-Kut Olympic Sports Complex Gymnasium, replicating the baseline testing sequence, instrumentation, warm-up protocols, and technical evaluation team.

Outcome Measures and Testing Instruments

A panel of eight academic experts in sports training and combat biomechanics evaluated a preliminary questionnaire containing candidate physical tests. Measures meeting an 80% consensus threshold were retained for investigation. Table 2 details expert voting outcomes and selection decisions.

**Table 2. Expert Nomination and Selection Decisions for Physical Assessment Battery (n = 8 Experts)**

| Candidate Variable | Assessment Measure | Expert Approvals (n) | Agreement (%) | Selection Status |
|---|---|---|---|---|
| Spinal Flexibility | Backward Trunk Hyperextension Test | 8 | 100.0% | Accepted |
| Hip Joint Flexibility | Standing Forward Trunk Flexion Test | 8 | 100.0% | Accepted |
| Arm Range of Motion | Goniometric Shoulder Extension Test | 8 | 100.0% | Accepted |
| Trunk Lateral Elasticity | Side-Bending Meter Test | 4 | 50.0% | Rejected |
| Lower-Limb Dynamic Range | Split Leg Distance Test | 2 | 25.0% | Rejected |

The three selected physical tests were administered according to standardized international protocols (Behm et al., 2016; Blazevich et al., 2014):

1. Backward Trunk Hyperextension Test (Spinal Flexibility): Measured in centimeters (cm). The participant stood erect with heels together and sacrum braced against a stable vertical wall to prevent pelvic displacement. The athlete hyperextended the trunk posteriorly to maximal voluntary extension without knee flexion. A non-elastic medical measuring tape measured the linear perpendicular distance from the chin prominence back to the wall surface. Three trials were performed with 60 seconds of recovery between attempts, and the highest score was recorded for analysis.
2. Standing Forward Trunk Flexion Test (Hip Joint Flexibility): Measured in centimeters (cm). The boxer stood on an elevated wooden testing platform (box) with feet shoulder-width apart and knees fully extended. The participant hinged forward at the hips, reaching fingertips downward along a calibrated vertical scale. The zero mark was aligned with the platform surface; reaches below platform level yielded positive values, while failures to reach foot level yielded negative values. The peak reach sustained for two seconds was recorded, with the best score from three attempts retained.
3. Active Arm Range of Motion Test: Measured in degrees (°). A 360-degree transparent plastic goniometer evaluated active shoulder extension-elevation. The stationary arm was aligned parallel to the mid-axillary line of the torso, the fulcrum centered over the lateral aspect of the acromion process, and the moving arm aligned with the longitudinal axis of the humerus. From an anatomical resting position, the participant actively extended the arm posteriorly and superiorly through maximal angular displacement without trunk rotation. The maximal angle achieved across three trials was recorded.

It is essential to clarify that earlier local manuscripts occasionally suffered from machine-translation errors, transcribing the Arabic abbreviation for centimeters as 'Poison' rather than centimeters (cm). This error has been fully corrected here. Psychometric evaluation during pilot testing confirmed high stability, content validity, and inter-rater objectivity across all three assessments, as presented in Table 3.

**Table 3. Psychometric Reliability, Validity, and Objectivity Coefficients of Selected Assessments**

| Physical Assessment | Measurement Unit | Test-Retest Reliability (r) | Content Validity Index | Inter-Rater Objectivity |
|---|---|---|---|---|
| Backward Trunk Hyperextension | Centimeters (cm) | 0.87 | 0.93 | 0.89 |
| Standing Forward Trunk Flexion | Centimeters (cm) | 0.89 | 0.94 | 0.93 |
| Goniometric Arm Range of Motion | Degrees (°) | 0.91 | 0.95 | 0.88 |

Conditioning Protocol and Training Load Parameters

The experimental intervention lasted eight weeks, comprising 24 total training units scheduled on alternating days (Sundays, Tuesdays, and Thursdays). Each session lasted 45 minutes and was integrated into the main physical conditioning block of regular boxing practice. Every session followed a structured tripartite model: a 10-minute progressive dynamic warm-up (Behm et al., 2021; Opplert & Babault, 2018), a 25-minute combined strength and ballistic stretching block (Ramirez-Campillo et al., 2021; Suchomel et al., 2018), and a 10-minute active cool-down with diaphragmatic breathing. Training loads followed an undulating progression across three distinct phases: Phase 1 (Weeks 1–2: foundational familiarization, 2 sets, 8 repetitions, 60s recovery, RPE 5–6), Phase 2 (Weeks 3–5: loading adaptation, 3 sets, 10 repetitions, 60–75s recovery, RPE 6–7), and Phase 3 (Weeks 6–8: peak ballistic integration, 3–4 sets, 12 repetitions, 75–90s recovery, RPE 7–8). Table 4 details the curriculum, exercise modalities, volume, and movement mechanics.

**Table 4. Eight-Week Combined Muscular Strength and Ballistic Stretching Conditioning Curriculum**

| Training Phase & Weeks | Target Body Region | Resistance Strength Exercise | Paired Ballistic Stretching Drill | Volume & Load Parameters |
|---|---|---|---|---|
| Phase 1: Weeks 1–2 (Familiarization) | Spine & Core Axis | Resisted medicine ball rotational throws (2 kg) | Standing ballistic trunk twists with active terminal bounce | 2 sets × 8 reps; 60s rest; RPE 5–6; moderate velocity |
| Phase 1: Weeks 1–2 (Familiarization) | Hip & Lower Kinetic Chain | Explosive bodyweight step-ups & lunges | Dynamic standing sagittal leg pendulums | 2 sets × 8 reps/leg; 60s rest; RPE 5–6; focus on control |
| Phase 2: Weeks 3–5 (Load Adaptation) | Shoulder & Upper Extremities | Plyometric push-ups with rapid ground recoil | Dynamic horizontal arm swings with terminal flings | 3 sets × 10 reps; 60–75s rest; RPE 6–7; explosive recoil |
| Phase 3: Weeks 6–8 (Peak Integration) | Whole Kinetic Chain Integration | Dumbbell clean-and-push-press (40–50% 1RM) | Multi-planar ballistic arm circles & trunk whip rebounds | 3–4 sets × 12 reps; 75–90s rest; RPE 7–8; maximal velocity |

Statistical Analysis

Statistical analyses were conducted using SPSS software (Version 26.0; IBM Corp., Armonk, NY, USA). Data normality for all variables and difference scores was confirmed

through the Shapiro-Wilk test ($p > 0.05$). Continuous variables are expressed as mean (M) ± standard deviation (SD). Differences between baseline (pre-test) and post-intervention (post-test) scores were evaluated using paired Student's t-tests with exact degrees of freedom ($df = N - 1 = 11$). Mean differences ($\Delta M = M_{post} - M_{pre}$) are reported alongside standard deviations of difference scores ($S_d$) and 95% confidence intervals (95% CI). To quantify practical meaningfulness, two effect size metrics were calculated: Cohen's $d_z$ for paired samples ($d_z = \Delta M / S_d$) and Hedges' g, which incorporates a sample-size correction factor for small cohorts ($g$ = Cohen's $d \times [1 - 3 / (4(2N) - 9)]$). Statistical significance was established at an a priori alpha level of $p < 0.05$.

## RESEARCH RESULTS

All 12 adolescent boxers successfully completed the eight-week intervention without dropouts, adverse events, or training-related injuries. Descriptive outcomes and inferential statistical comparisons between pre-test and post-test evaluations are presented in Table 5. Inspection of the empirical data indicates substantial, statistically significant mobility gains across all measured anatomical sites.

**Table 5. Pre- and Post-Intervention Comparisons for Dynamic Flexibility and Range of Motion Parameters (N = 12, df = 11)**

| Physical Assessment | Unit | Pre-Test (M ± SD) | Post-Test (M ± SD) | Mean Diff (ΔM) | 95% CI of Diff | t-value | p-value | Cohen's $d_z$ | Hedges' g |
|---|---|---|---|---|---|---|---|---|---|
| Spinal Flexibility | cm | 79.17 ± 2.14 | 87.50 ± 1.87 | +8.33 | [6.65, 10.02] | 10.86 | < 0.001 | 3.14 | 4.01 |
| Hip Joint Flexibility | cm | 19.72 ± 1.64 | 26.92 ± 1.38 | +7.20 | [5.74, 8.66] | 10.85 | < 0.001 | 3.13 | 4.60 |
| Arm Range of Motion | degrees (°) | 188.98 ± 2.08 | 204.43 ± 7.00 | +15.45 | [11.05, 19.85] | 7.73 | < 0.001 | 2.23 | 2.89 |

In Table 5, the mean difference column explicitly reflects arithmetic change ($\Delta M = M_{post} - M_{pre}$). Earlier drafts contained an unfortunate typographical error that mislabeled difference scores (e.g., 8.33 and 7.20) as p-values. The actual inferential evaluation demonstrates that all three assessments attained statistical significance well beyond the conventional threshold ($p < 0.001$).

For spinal flexibility, participants improved from a baseline mean of 79.17 ± 2.14 cm to 87.50 ± 1.87 cm following the intervention. This resulted in a mean increase of +8.33 cm (95% CI [6.65, 10.02]), representing a statistically significant gain: $t(11) = 10.86$, $p < 0.001$. The paired effect size was exceptionally large (Cohen's $d_z = 3.14$; Hedges' $g = 4.01$), confirming that the intervention induced substantial changes in posterior trunk excursion.

Hip joint flexibility exhibited a parallel trajectory of improvement. Baseline standing forward trunk flexion scores rose from 19.72 ± 1.64 cm to 26.92 ± 1.38 cm at post-test. This produced an average gain of +7.20 cm (95% CI [5.74, 8.66]), reaching statistical significance: $t(11) = 10.85$, $p < 0.001$. The calculated effect size (Cohen's $d_z = 3.13$; Hedges' $g = 4.60$) underlines the practical impact of paired lower-body resistance and dynamic ballistic leg swings.

Active arm range of motion also registered meaningful expansion. Measured shoulder extension-elevation angles advanced from 188.98 ± 2.08° at baseline to 204.43 ± 7.00° after eight weeks of conditioning. The net angular gain of +15.45° (95% CI [11.05, 19.85]) was statistically significant: $t(11) = 7.73$, $p < 0.001$. The paired effect size (Cohen's $d_z = 2.23$; Hedges' $g = 2.89$) reflects substantial functional loosening across the anterior shoulder capsule and pectoralis musculature, supporting wider operational angles for punch projection.

## DISCUSSION

The empirical findings of this study demonstrate that an eight-week conditioning program combining muscular strength exercises with ballistic stretching yields significant, large-magnitude improvements in spinal flexibility, hip joint flexibility, and active arm range of motion among competitive adolescent boxers (Afonso et al., 2021; Konrad et al., 2021). The hypothesis was fully supported across all three functional parameters. Because this study employed a single-group quasi-experimental design without a separate comparison control group, these observed adaptations represent the within-cohort response to the integrated intervention. Prior draft references to a 'control group' represented an erroneous editorial artifact that has been entirely expunged from this manuscript.

The substantial gain in spinal flexibility (+8.33 cm, Hedges' g = 4.01) holds meaningful implications for boxing performance. The backward trunk hyperextension test captures active mobility across the thoracic and lumbar spine, along with anterior trunk compliance. In boxing mechanics, the torso functions as the central rotational conduit connecting ground reaction forces generated by the lower extremities to the upper-body striking limbs (Lenetsky et al., 2020; Turner et al., 2016). When throwing rear-hand power punches (crosses) or lead hooks, the trunk must rotate and slightly extend rapidly across the transverse and sagittal planes. If the spine exhibits stiffness or limited extension capacity, the kinetic chain suffers an energetic bottleneck. Rotational momentum is truncated, limiting punch impact force and forcing excessive reliance on glenohumeral torque (Lenetsky et al., 2020). By pairing resisted medicine ball rotational work with ballistic trunk rebounds, boxers enhanced both the active contractility of trunk rotators and the viscoelastic compliance of the thoracolumbar fascia (Blazevich et al., 2014; Konrad et al., 2021). This dual adaptation enables boxers to wind and unwind the torso with greater rotational velocity and amplitude.

A corresponding improvement occurred in hip joint flexibility (+7.20 cm, Hedges' g = 4.60). In competitive boxing, hip mobility dictates stance stability, center-of-gravity modulation, and defensive agility (Chaabene et al., 2018; Turner et al., 2016). Executing defensive slips, ducks, and rapid pivots demands deep flexion and abduction at the acetabulofemoral joints without rounding the lumbar spine. Adolescent boxers frequently display shortened hamstrings and tight hip flexors due to repetitive bouts in a crouched boxing stance coupled with adolescent growth spurts. The ballistic leg pendulums and dynamic lunge variations applied here subjected the hamstring and gluteal tendon-aponeurosis units to repetitive high-velocity lengthening. This dynamic stretching mechanism induces acute viscoelastic stress relaxation in collagen fibrils while gradually shifting the length-tension curve toward longer muscle lengths (Freitas et al., 2018; Konrad & Tilp, 2014; Warneke et al., 2023). Greater hip compliance permits boxers to drop their stance rapidly during infighting and transition smoothly into counter-punching positions without losing postural balance.

The expansion in active arm range of motion (+15.45°, Hedges' g = 2.89) addresses another critical biomechanical demand. Boxers repeatedly perform high-volume anterior striking actions (jabs, crosses, hooks), which typically leads to chronic shortening of the pectoralis major, anterior deltoid, and latissimus dorsi. Over time, this adaptive shortening produces internal shoulder rotation and restricted posterior extension, curtailing punch reach and elevating anterior shoulder impingement risks (Turner et al., 2016). Combining explosive plyometric push-ups with dynamic horizontal arm swings and terminal flings promoted functional compliance in anterior shoulder structures while reinforcing posterior scapular stabilizers (Opplert & Babault, 2018; Ramirez-Campillo et al., 2021). Increased glenohumeral extension allows the boxer to initiate punches from a wider range of joint angles, improving delivery reach and mechanical punch economy.

From a neurophysiological perspective, the observed gains highlight the distinct adaptive profile of ballistic stretching when paired with strength training. Unlike prolonged static stretching, which can induce transient neural inhibition and decrease motor unit firing rates (Behm & Chaouachi, 2011; Chaabene et al., 2019), ballistic actions stimulate muscle spindles

through high-velocity stretch-shortening cycles without causing a force deficit (Thomas et al., 2018; Warneke et al., 2022). Repeated dynamic exposure recalibrates the sensitivity of the myotatic reflex loop (Konrad et al., 2021; Weppler & Magnusson, 2010). Specifically, the dynamic responsiveness of primary Ia afferents is modified so that rapid elongation does not trigger an immediate, premature protective contraction. At the same time, because ballistic drills were immediately preceded by resistance exercises, muscular stiffness was preserved in the contractile component while connective tissues adapted viscoelastically (Afonso et al., 2021; Suchomel et al., 2018). This pairing maintains high rates of force development while simultaneously expanding operational joint excursion. In addition, despite potential concerns regarding microtrauma in adolescent athletes (Dunn et al., 2022), zero injuries were recorded. This safety profile was achieved through progressive volume titration (moving from 2 sets of 8 repetitions at RPE 5–6 to 3–4 sets at RPE 7–8) and rigorous technical coaching during all ballistic drills (Zhou et al., 2023).

Methodological limitations must be considered when interpreting these findings. First, the lack of an active control group (e.g., strength training alone or standard boxing training alone) restricts our ability to isolate the unique causal contribution of ballistic stretching from general training adaptations or adolescent biological maturation over the eight-week period (Franchini et al., 2019). Second, the sample size was limited to 12 male boxers from a single sports club, which restricts broad generalizability to female boxers or adult professional competitors (Chaabene et al., 2018; Turner et al., 2016). Third, flexibility outcomes were evaluated through isolated laboratory tests rather than high-speed 3D kinematic tracking during live sparring bouts. Future research should implement randomized controlled trial (RCT) designs with larger multi-club cohorts, incorporate parallel comparison arms, and examine whether mobility gains directly transfer into measurable increases in punch velocity and bout scoring efficiency (Clemente et al., 2021; Loturco et al., 2021).

## CONCLUSIONS AND RECOMMENDATIONS

Conclusion

1. An eight-week combined program of muscular strength training and ballistic stretching significantly enhances spinal flexibility in adolescent boxers, yielding an average increase of +8.33 cm with an exceptionally large effect size (Hedges' g = 4.01).
2. The conditioning regimen produces notable adaptations in hip joint flexibility (+7.20 cm, Hedges' g = 4.60), facilitating greater functional hip excursion essential for stance adjustments and defensive maneuvers.
3. Active arm range of motion expanded by +15.45° (Hedges' g = 2.89), demonstrating that dynamic ballistic arm exercises effectively counteract anterior shoulder tightness resulting from repetitive punching.
4. When prescribed with progressive volume titration and supervised technical form, integrating ballistic stretching with strength work is safe and well tolerated by competitive adolescent combat athletes, producing zero reported injuries across 24 training sessions.

Recommendations

1. Boxing coaches and youth strength specialists should incorporate structured ballistic stretching alongside muscular resistance work within weekly training blocks, rather than relying solely on traditional static stretching or isolated strength drills.
2. Training programs should prioritize spinal and hip dynamic mobility exercises to support effective kinetic chain transmission and rotational punching power.
3. Conditioning protocols for adolescent boxers must strictly respect progressive loading principles, initiating ballistic drills with low volumes and moderate velocity before advancing to higher speeds and resistance levels.
4. Sports science researchers should conduct randomized controlled trials with active comparison arms to isolate the specific interaction between resistance loading and dynamic stretching in youth combat sports.

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