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The effect of Iso-inertial flywheel training on hip eccentric strength and its impact on Suplex technique success in senior Greco-Roman wrestlers

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Abstract
Background: The suplex technique in Greco-Roman wrestling requires exceptional hip eccentric strength for controlled execution and safe landing. Iso-inertial flywheel training offers a unique approach to develop eccentric strength through variable resistance and overload mechanisms that closely match the biomechanical demands of wrestling techniques.
Objective: This study aimed to investigate the effects of iso-inertial flywheel training on hip eccentric strength and its impact on suplex technique success in senior Greco-Roman wrestlers.
Methods: Twenty-four senior Greco-Roman wrestlers (aged 23-28 years) from four wrestling clubs in Kirkuk were randomly assigned to experimental group (n=12) receiving iso-inertial flywheel training, and control group (n=12) following traditional strength training. The 10-week intervention included 3 sessions per week of progressive flywheel training targeting hip extensors and flexors. Measurements included hip eccentric strength (isokinetic dynamometry), suplex success rate, execution quality, and landing control assessment.
Results: The experimental group demonstrated significant improvements compared to the control group ($p<0.05$) in hip eccentric strength at 60°/s (242±28 to 311±32 Nm, +28.5%), hip eccentric strength at 180°/s (189±22 to 248±26 Nm, +31.2%), suplex success rate (64.2±8.1% to 87.5±6.3%, +36.3%), technique execution quality (6.8±1.0 to 8.9±0.7 points, +30.9%), and landing control score (7.1±0.9 to 9.2±0.6 points, +29.6%).
Conclusion: Iso-inertial flywheel training effectively improved hip eccentric strength and suplex technique performance in Greco-Roman wrestlers. The training protocol enhanced both strength capacity and technical execution quality, demonstrating superior adaptations compared to traditional strength training methods.

Keywords: Iso-inertial training, flywheel device, eccentric strength, Greco-Roman wrestling, suplex technique

1. Introduction

1.1 Background and Significance

Greco-Roman wrestling stands as one of the most technically demanding combat sports, requiring exceptional strength, power, and neuromuscular control across multiple movement planes (Al-Rubaie & Al-Kaabi, 2022, p. 134) [1]. The sport's unique rule set, which prohibits attacks below the waist, places particular emphasis on upper body and hip strength for successful execution of throwing techniques. Among these techniques, the suplex represents one of the most spectacular and technically challenging maneuvers, requiring precise timing, exceptional strength, and controlled eccentric muscle actions (Mirzaei *et al*., 2021, p. 445) [16]. The suplex technique involves lifting an opponent overhead and executing a backward throwing motion that requires significant hip eccentric strength for controlled descent and safe landing (Tunnemann & Curby, 2018, p. 89) [23]. The eccentric phase of this movement is critical not only for technique success but also for injury prevention, as wrestlers must control both their own body weight and that of their opponent during the landing phase (García-Pallarés & Izquierdo, 2020, p. 567) [13].

Iso-inertial flywheel training has emerged as an innovative strength training methodology that utilizes rotational inertia to provide variable resistance throughout the range of motion (Sabido *et al*., 2017, p. 234) [19]. This training modality offers unique advantages over traditional weight training, particularly in its ability to provide eccentric overload through the storage and release of kinetic energy during the flywheel's rotation cycle (Núñez *et al*., 2020, p. 178) [17].

The biomechanical characteristics of flywheel training closely match the demands of wrestling techniques, particularly those requiring eccentric strength and control (Maroto-Izquierdo *et al*., 2017, p. 423) [15]. The accommodating resistance provided by flywheel devices allows for maximal muscle activation throughout the entire range of motion, potentially leading to superior strength adaptations compared to traditional training methods (Petré *et al*., 2018, p. 345) [18].

Recent research has highlighted the importance of eccentric strength in wrestling performance, particularly for techniques involving lifting and throwing motions (Thompson & Wilson, 2022, p. 456) [22]. The ability to generate and control high forces during eccentric muscle actions represents a critical performance factor that directly influences technique execution quality and injury risk in wrestling contexts (Al-Samarrai & Al-Dulaimi, 2021, p. 189) [2].

1.2 Problem Statement

Current strength training methodologies in Greco-Roman wrestling often fail to adequately address the specific eccentric strength demands of suplex techniques. Traditional weight training approaches typically provide constant external resistance that does not match the variable force requirements of wrestling movements, potentially limiting the transfer of strength gains to competitive performance (Abdullah & Mahmoud, 2022, p. 234) [5].

The suplex technique presents unique biomechanical challenges, requiring wrestlers to generate maximal concentric force during the lifting phase while simultaneously preparing for controlled eccentric muscle actions during the descent and landing phases. Many wrestlers demonstrate adequate lifting strength but struggle with the eccentric control necessary for safe and effective technique completion (Hussein & Jaafar, 2021, p. 167) [6].

The limited availability of specialized training equipment in many wrestling programs necessitates the development of effective training protocols using innovative and accessible equipment. Flywheel devices represent an ideal solution, offering variable resistance training capabilities in a relatively compact and portable format (Khalid & Nabil, 2022, p. 123) [7].

Furthermore, the lack of comprehensive research examining the specific effects of iso-inertial flywheel training on wrestling performance represents a significant gap in the scientific literature. While previous studies have investigated flywheel training in various athletic populations, few have specifically examined its application to combat sports and wrestling techniques requiring eccentric strength control.

1.3 Research Objectives

Primary Objective: To investigate the effects of iso-inertial flywheel training on hip eccentric strength and its impact on suplex technique success in senior Greco-Roman wrestlers.

Secondary Objectives

1. To evaluate the impact of flywheel training on hip eccentric strength at different angular velocities
2. To assess changes in suplex technique success rate and execution quality
3. To examine improvements in landing control and technique safety parameters
4. To analyze the relationship between eccentric strength gains and technical performance enhancements
5. To investigate changes in strength ratios and muscle balance around the hip joint
6. To provide evidence-based recommendations for wrestling-specific strength training program design

1.4 Research Hypotheses

Primary Hypothesis: Iso-inertial flywheel training will significantly improve hip eccentric strength and suplex technique success in senior Greco-Roman wrestlers compared to traditional strength training methods.

Secondary Hypotheses

1. Participants in the experimental group will demonstrate greater improvements in hip eccentric strength at multiple angular velocities
2. The experimental group will show superior enhancements in suplex success rate and execution quality
3. There will be significant improvements in landing control and technique safety measures in the experimental group
4. A significant positive correlation will exist between eccentric strength improvements and technical performance gains
5. The experimental group will exhibit improved strength ratios and muscle balance around the hip joint
6. The flywheel training protocol will produce greater training adaptations compared to traditional strength training methods

1.5 Research Delimitations

Population Delimitations

- Senior Greco-Roman wrestlers aged 23-28 years
- Minimum 8 years of competitive wrestling experience
- Current participation in national level competitions
- No history of major hip or lower back injuries in the past 18 months
- Baseline hip eccentric strength ≥ 200 Nm at 60°/s

Temporal Delimitations

- **Study duration:** 12 weeks (2 weeks baseline + 10 weeks intervention)
- **Training frequency:** 3 sessions per week
- **Session duration:** 45-60 minutes per session
- **Testing periods:** Pre-intervention and post-intervention

Spatial Delimitations

- Four wrestling clubs in Kirkuk, Iraq
- University biomechanics laboratory for strength testing
- Standardized training facilities with flywheel equipment
- International standard wrestling mats for technical assessments

1.6 Operational Definitions

Iso-inertial Flywheel Training: A resistance training method utilizing rotating flywheel devices that provide accommodating resistance through inertial loading, enabling eccentric overload through the storage and release of kinetic energy.

Hip Eccentric Strength: The maximum force-generating capacity of hip muscles during lengthening contractions, typically measured using isokinetic dynamometry at specified angular velocities.

Suplex Technique: A Greco-Roman wrestling throw involving lifting an opponent overhead and executing a backward arching motion to bring the opponent to the mat while maintaining control.

Landing Control: The ability to safely and effectively control body position and movement during the landing phase of throwing techniques, assessed through biomechanical and observational measures.

Technique Execution Quality: The overall effectiveness and precision of suplex performance as evaluated by qualified wrestling coaches using standardized criteria.

2. Literature Review

2.1 Biomechanical Demands of Suplex Techniques

The suplex technique in Greco-Roman wrestling represents one of the most biomechanically complex movements in combat sports. Al-Zubaidi and Al-Ameri (2022, p. 189) [4] conducted detailed biomechanical analysis of suplex execution in elite Iraqi wrestlers and identified distinct phases requiring different strength qualities. The initial lifting phase demands maximal concentric strength from hip extensors and spinal erectors, while the throwing and landing phases require exceptional eccentric strength and neuromuscular control.

Kraemer *et al.* (2020, p. 378) [14] investigated the force production patterns during various Greco-Roman wrestling techniques and found that suplex techniques generated peak forces exceeding 2.5 times body weight during the lifting phase, followed by eccentric forces of up to 3.2 times body weight during the controlled descent. The study emphasized the critical importance of eccentric strength for both performance and injury prevention in these high-risk maneuvers.

Mohammed and Ali (2021, p. 234) [8] examined the muscle activation patterns during suplex execution using electromyography and reported that hip extensors demonstrated the highest activation during the concentric phase (>90% maximum voluntary contraction), while hip flexors and extensors showed co-activation patterns exceeding 80% during the eccentric landing phase. This finding highlights the complex neuromuscular coordination required for successful technique execution.

Yoon and Kim (2019, p. 445) [25] provided comprehensive kinematic analysis of suplex techniques and established that successful execution required hip extension velocities exceeding 400°/s during the lifting phase, followed by controlled eccentric velocities of 200-300°/s during descent. The study found strong correlations between eccentric strength capacity and technique success rates ($r = 0.78$, $p<0.01$).

2.2 Eccentric Strength in Wrestling Performance

The role of eccentric strength in wrestling performance has gained increasing attention due to its critical importance in technique execution and injury prevention. Franchini *et al.* (2020, p. 567) [12] conducted a systematic review of strength qualities in combat sports and identified eccentric strength as a key predictor of throwing technique success. Their analysis revealed that athletes with superior eccentric strength demonstrated 34% higher success rates in high-amplitude throwing techniques.

Saad and Husam (2021, p. 289) [9] specifically examined eccentric strength characteristics in Iraqi wrestlers and found significant differences between elite and sub-elite performers. Elite wrestlers demonstrated 28% greater hip eccentric strength at slow velocities (60°/s) and 35% greater strength at fast velocities (180°/s) compared to their sub-elite counterparts. The study established normative values for hip eccentric strength in wrestling populations.

Slimani *et al.* (2019, p. 612) [20] investigated the relationship between eccentric strength and injury rates in combat sports athletes. Their longitudinal study demonstrated that wrestlers with hip eccentric strength deficits (eccentric: concentric ratio < 0.80) experienced 2.3 times higher injury rates compared to those with balanced strength ratios. This finding emphasizes the protective role of eccentric strength in wrestling contexts.

2.3 Iso-inertial Flywheel Training Principles

Iso-inertial flywheel training represents a paradigm shift in resistance training methodology, utilizing the principles of rotational inertia to provide unique loading characteristics. Sabido *et al.* (2017, p. 234) [19] provided comprehensive analysis of flywheel training mechanics and demonstrated that this modality enables eccentric overload through the storage and release of kinetic energy during the flywheel's rotation cycle.

Maroto-Izquierdo *et al.* (2017, p. 423) [15] conducted biomechanical analysis of flywheel training and found that this method produced 1.3-1.8 times greater eccentric forces compared to traditional weight training at equivalent perceived exertion levels. The accommodating resistance characteristics of flywheel devices enabled maximal muscle activation throughout the entire range of motion, potentially optimizing training adaptations.

Núñez *et al.* (2020, p. 178) [17] investigated the physiological responses to flywheel training in athletic populations and reported superior adaptations in eccentric strength (26% vs. 14%), muscle architecture (8.4% vs. 3.2% fascicle length increase), and neuromuscular activation patterns compared to traditional resistance training. The study attributed these benefits to the unique loading characteristics and eccentric emphasis of flywheel training.

Petré *et al.* (2018, p. 345) [18] examined the specificity of flywheel training adaptations and found that improvements were most pronounced in movements requiring eccentric control and variable force production. This finding supports the potential application of flywheel training to wrestling techniques characterized by complex force-velocity requirements.

Proper and efficient breathing plays a vital role in the performance of athletes. It gives them the ability to get rid of excess carbon dioxide in the body and get the oxygen needed for the muscles during strenuous exercises and intense physical performance. (2024, p.15)

2.4 Flywheel Training in Athletic Populations

The application of flywheel training in athletic populations has gained significant research attention due to its potential for enhancing sport-specific performance. Vicens-Bordas *et al.* (2018, p. 456) [24] investigated flywheel training effects in soccer players and found significant improvements in eccentric hamstring strength (31%), jumping performance (12%), and sprint acceleration (8%) following 6-week interventions. The study highlighted the transfer of flywheel training adaptations to sport-specific movement patterns.

Khalid and Nabil (2022, p. 167) [7] specifically examined flywheel training applications in Iraqi athletes and demonstrated significant improvements in eccentric strength (24% increase), power output (18% improvement), and functional movement quality scores. Their study emphasized the practical applicability of flywheel training in resource-limited training environments.

De Hoyo *et al.* (2015, p. 289) [11] conducted a comparative study examining flywheel training versus traditional weight training in team sport athletes. The flywheel group demonstrated superior improvements in eccentric strength (28% vs. 16%), reactive strength index (22% vs. 12%), and change of direction performance (15% vs. 8%) compared to the traditional training group.

Hussein and Jaafar (2021, p. 234) [6] investigated flywheel training adaptations in combat sports athletes and found significant improvements in both concentric and eccentric strength measures. Their study reported 19% improvement in eccentric hip strength and 23% enhancement in throwing technique success rates following 8-week flywheel training interventions.

it will be possible to provide specific and codified scientific and practical recommendations to improve the overall performance of teams and develop the level of training and qualification effectively. (2024, p. 44)

2.5 Training Adaptations and Mechanisms

The mechanisms underlying flywheel training adaptations have been extensively studied to understand the superior outcomes observed in various athletic populations. Todos-Fajardo *et al.* (2016, p. 378) [22] examined the neuromuscular adaptations to flywheel training and found significant increases in motor unit recruitment (18%), firing frequency (14%), and intermuscular coordination patterns. These neural adaptations contributed to enhanced force production and movement control capabilities.

Beato *et al.* (2020, p. 445) [10] investigated the structural adaptations to flywheel training using ultrasonography and found significant increases in muscle fascicle length (8.9%), pennation angle optimization (5.2%), and muscle thickness (6.7%) compared to traditional training methods. These architectural changes supported the enhanced force-velocity characteristics observed following flywheel training.

Al-Taie and Al-Naimi (2021, p. 312) [3] examined the metabolic responses to flywheel training in Iraqi athletes and reported unique physiological stress patterns characterized by elevated lactate accumulation and enhanced anaerobic capacity. The study suggested that flywheel training provides both strength and metabolic training stimuli, potentially optimizing multiple performance factors simultaneously.

Thompson and Wilson (2022, p. 567) [22] conducted longitudinal analysis of flywheel training adaptations and found that improvements in eccentric strength were maintained for up to 8 weeks following training cessation, while concentric strength gains declined more rapidly. This finding supports the potential for long-term retention of flywheel training benefits.

3. Methodology

3.1 Research Design

This study employed a randomized controlled trial design with pre-post measurements to examine the effects of iso-inertial flywheel training on hip eccentric strength and suplex technique performance. The experimental design utilized a parallel group structure with participants randomly assigned to either the experimental group (flywheel training) or control group (traditional strength training).

3.2 Participants

Sample Size Calculation: Based on previous research by Saad and Husam (2021, p. 291) [9] and using G*Power 3.1.9.7 software, a sample size of 24 participants was calculated to detect a large effect size (d = 0.8) with 85% power and α = 0.05, accounting for a 10% dropout rate.

Inclusion Criteria

- Male senior Greco-Roman wrestlers aged 23-28 years
- Minimum 8 years of competitive wrestling experience
- Current participation in national level competitions
- Baseline hip eccentric strength ≥ 200 Nm at 60°/s
- No history of major hip or lower back injuries in the past 18 months
- Demonstrated proficiency in suplex technique execution

Exclusion Criteria

- Current injury or medical condition affecting training capacity
- Previous experience with flywheel training (>4 weeks)
- Concurrent participation in other research studies
- Use of performance-enhancing substances
- Inability to commit to the full training program duration

Recruitment and Randomization: Participants were recruited from four wrestling clubs in Kirkuk, Iraq: Kirkuk Sports Club, Petroleum Sports Club, Kirkuk University Wrestling Club, and Youth Sports Club. Following informed consent and baseline testing, participants were randomly assigned to groups using block randomization stratified by club affiliation. The final sample consisted of 24 wrestlers: experimental group (n=12, age: 25.2±1.8 years, body mass: 82.4±9.3 kg) and control group (n=12, age: 25.4±1.6 years, body mass: 81.7±8.9 kg).

3.3 Ethical Considerations

This study was approved by the Research Ethics Committee of the University of Kirkuk (Ethics Approval Number: UoK/CPES/2023/089) and the Iraqi Ministry of Youth and Sports Research Committee (Approval Number: MYS/RC/2023/167). All participants provided written informed consent after receiving comprehensive information about study procedures, potential risks, and benefits.

3.4 Testing Procedures

Pre-testing Protocol: All participants underwent comprehensive baseline testing over a 1-week period. Testing sessions were conducted at consistent times (9:00 AM-12:00 PM) to control for circadian rhythm effects. Participants were instructed to avoid intensive training 48 hours before testing, maintain normal dietary habits, and avoid caffeine intake 4 hours before assessments.

Testing Battery

1. Anthropometric Measurements

- Height and body mass using calibrated equipment
- Body composition via bioelectrical impedance analysis
- Hip flexibility assessment using goniometry

2. Hip Eccentric Strength Assessment

- **Equipment:** Biodex System 4 isokinetic dynamometer
- **Position:** Supine position with hip at 90° flexion
- **Protocol:** Maximal eccentric contractions at 60°/s and 180°/s

- **Variables:** Peak torque, total work, eccentric:concentric ratio

3. Suplex Technique Performance Assessment
- **Success Rate:** Percentage of successful techniques out of 15 attempts
- **Execution Quality:** 10-point scale assessed by certified coaches
- **Landing Control:** Biomechanical analysis using force plates
- **Technique Time:** Duration from initiation to completion

4. Neuromuscular Performance Tests
- **Countermovement Jump:** Peak power and jump height
- **Reactive Strength Index:** Drop jump from 30 cm height
- **Hip Abduction Strength:** Manual muscle testing

3.5 Training Interventions
Experimental Group - Iso-inertial Flywheel Training:
The flywheel training protocol was designed based on established principles (Sabido *et al*., 2017) [19] and adapted for wrestling-specific applications. Training sessions were conducted 3 times per week with 48-hour recovery periods.

Equipment Specifications
- **Flywheel Device:** EXXENTRIC kBox4 Pro with variable inertial loads
- **Inertial Settings:** 0.025-0.075 kg·m² depending on exercise and progression
- **Safety Features:** Emergency brake system and safety straps

Session Structure
- **Warm-up:** 10 minutes (dynamic mobility, activation exercises)
- **Flywheel training:** 35-40 minutes (4-6 exercises)
- **Technical practice:** 10 minutes (suplex drilling)
- **Cool-down:** 10 minutes (static stretching, recovery)

Training Progression
Weeks 1-2: Familiarization Phase
- **Volume:** 3 sets × 8 repetitions
- **Inertia:** 0.025 kg·m² (low load)
- **Rest:** 2-3 minutes between sets
- **Focus:** Movement quality and technique mastery

Weeks 3-4: Development Phase
- **Volume:** 4 sets × 6 repetitions
- **Inertia:** 0.050 kg·m² (moderate load)
- **Rest:** 2-3 minutes between sets
- **Focus:** Force production and eccentric emphasis

Weeks 5-7: Intensification Phase
- **Volume:** 4 sets × 6 repetitions
- **Inertia:** 0.075 kg·m² (high load)
- **Rest:** 3-4 minutes between sets
- **Focus:** Maximal eccentric overload

Weeks 8-10: Peaking Phase
- **Volume:** 3 sets × 8 repetitions
- **Inertia:** 0.050 kg·m² (moderate load)
- **Rest:** 2-3 minutes between sets
- Focus: Power expression and technique integration

Primary Exercises
1. Hip Extension (Prone)
- **Starting position:** Prone with flywheel strap attached to ankles
- **Movement:** Hip extension against flywheel resistance
- **Focus:** Eccentric control during return phase

2. Hip Flexion (Supine)
- **Starting position:** Supine with flywheel strap attached to thighs
- **Movement:** Hip flexion against flywheel resistance
- **Focus:** Eccentric strength in hip flexors

3. Romanian Deadlift
- **Starting position:** Standing with flywheel strap attached to harness
- **Movement:** Hip hinge pattern with emphasis on eccentric control
- **Focus:** Posterior chain strength and suplex-specific movement

4. Lateral Hip Strength
- **Starting position:** Side-lying with flywheel strap attached to upper leg
- **Movement:** Hip abduction/adduction pattern
- **Focus:** Hip stability and lateral strength

Control Group - Traditional Strength Training:
The control group followed a traditional strength training program using free weights and machines, matched for training frequency and duration.

Session Structure
- **Warm-up:** 10 minutes
- **Strength training:** 35-40 minutes (4-6 exercises)
- **Technical practice:** 10 minutes (suplex drilling)
- **Cool-down:** 10 minutes

Primary Exercises
- Romanian deadlifts with barbell
- Hip thrusts with barbell
- Bulgarian split squats
- Hip abduction machine
- Nordic hamstring curls
- Good mornings

3.6 Data Collection
Data collection was supervised by certified exercise physiologists and experienced wrestling coaches. All testing equipment was calibrated according to manufacturer specifications. Standardized instructions and demonstrations were provided to all participants.

Quality Control Measures
- Test-retest reliability coefficients > 0.90 for all measures
- Blinded assessment for technical skill evaluation
- Standardized environmental conditions
- Consistent recovery protocols between tests

3.7 Statistical Analysis
Statistical analyses were performed using SPSS version 28.0. Descriptive statistics (mean ± standard deviation) were calculated for all variables. Data normality was assessed using the Shapiro-Wilk test.

Primary Analyses
- Two-way repeated measures ANOVA (group × time) for each dependent variable
- Effect sizes calculated using Cohen's d and partial eta-squared
- Post-hoc comparisons using Bonferroni correction
- Independent t-tests for between-group comparisons

Secondary Analyses
- Pearson correlation analysis for strength-performance relationships
- Multiple regression analysis to identify predictors of technique improvement
- Effect size interpretations: small (d = 0.2), medium (d = 0.5), large (d = 0.8)

4. Results
4.1 Participant Characteristics and Compliance
All 24 participants completed the study with 96.8% adherence to training programs. No injuries occurred during the intervention period. Baseline characteristics showed no significant differences between groups (Table 1).

Table 1: Baseline Participant Characteristics

Variable	Experimental Group (n=12)	Control Group (n=12)	p-value	Effect Size (d)
Age (years)	25.2±1.8	25.4±1.6	0.782	0.12
Height (cm)	178.4±7.2	177.9±6.8	0.856	0.07
Body mass (kg)	82.4±9.3	81.7±8.9	0.843	0.08
Wrestling experience (years)	12.8±3.1	12.4±2.9	0.739	0.13
Hip eccentric strength 60°/s (Nm)	242±28	238±31	0.728	0.14

4.2 Hip Eccentric Strength Outcomes
4.2.1 Hip Eccentric Strength at 60°/s
The experimental group demonstrated significant improvements in hip eccentric strength at 60°/s compared to the control group (Table 2).

Table 2: Hip Eccentric Strength at 60°/s Results

Group	Pre-test (Nm)	Post-test (Nm)	Change (Nm)	% Change	Effect Size ($\eta^2 p$)
Experimental	242±28	311±32*†	+69±18	+28.5%	0.891
Control	238±31	256±29*	+18±12	+7.6%	0.423

*Significantly different from pre-test (p<0.05)
†Significantly different from control group (p<0.05)

4.2.2 Hip Eccentric Strength at 180°/s
Similar improvements were observed at higher angular velocities (Table 3).

Table 3: Hip Eccentric Strength at 180°/s Results

Group	Pre-test (Nm)	Post-test (Nm)	Change (Nm)	% Change	Effect Size ($\eta^2 p$)
Experimental	189±22	248±26*†	+59±15	+31.2%	0.867
Control	186±25	201±23*	+15±11	+8.1%	0.378

*Significantly different from pre-test (p<0.05)
†Significantly different from control group (p<0.05)

4.3 Suplex Technique Performance
4.3.1 Success Rate
The experimental group showed dramatic improvements in suplex success rate (Table 4).

Table 4: Suplex Success Rate Results

Group	Pre-test (%)	Post-test (%)	Change (%)	% Change	Effect Size ($\eta^2 p$)
Experimental	64.2±8.1	87.5±6.3*†	+23.3±5.7	+36.3%	0.923
Control	63.8±7.9	71.4±8.2*	+7.6±4.3	+11.9%	0.456

*Significantly different from pre-test (p<0.05)
†Significantly different from control group (p<0.05)

4.3.2 Execution Quality
Technique execution quality demonstrated significant improvements in the experimental group (Table 5).

Table 5: Suplex Execution Quality Results

Group	Pre-test (points)	Post-test (points)	Change (points)	% Change	Effect Size ($\eta^2 p$)
Experimental	6.8±1.0	8.9±0.7*†	+2.1±0.6	+30.9%	0.884
Control	6.7±1.1	7.4±0.9*	+0.7±0.5	+10.4%	0.334

*Significantly different from pre-test (p<0.05)
†Significantly different from control group (p<0.05)

4.3.3 Landing Control
Landing control scores showed substantial improvements following flywheel training (Table 6).

Table 6: Landing Control Score Results

Group	Pre-test (points)	Post-test (points)	Change (points)	% Change	Effect Size (η^2p)
Experimental	7.1±0.9	9.2±0.6*†	+2.1±0.7	+29.6%	0.856
Control	7.0±1.0	7.6±0.8*	+0.6±0.4	+8.6%	0.367

*Significantly different from pre-test ($p<0.05$)
†Significantly different from control group ($p<0.05$)

4.4 Correlation Analysis
Strong correlations were found between eccentric strength improvements and technical performance measures (Table 7).

Table 7: Correlation Matrix between Variables (Change Scores)

Variable	1	2	3	4	5
1. Hip Eccentric Strength 60°/s	-				
2. Hip Eccentric Strength 180°/s	0.847**	-			
3. Suplex Success Rate	0.793**	0.768**	-		
4. Execution Quality	0.756**	0.721**	0.889**	-	
5. Landing Control	0.812**	0.779**	0.834**	0.923**	-

**$p<0.01$

4.5 Between-Group Comparisons
Independent t-tests revealed significant between-group differences for all primary outcome measures at post-test (Table 8).

Table 8: Between-Group Comparisons at Post-Test

Variable	Experimental Group	Control Group	t-value	p-value	Cohen's d
Hip Eccentric Strength 60°/s (Nm)	311±32	256±29	4.78	<0.001	1.82
Hip Eccentric Strength 180°/s (Nm)	248±26	201±23	4.93	<0.001	1.93
Suplex Success Rate (%)	87.5±6.3	71.4±8.2	5.67	<0.001	2.18
Execution Quality (points)	8.9±0.7	7.4±0.9	4.89	<0.001	1.89
Landing Control (points)	9.2±0.6	7.6±0.8	5.34	<0.001	2.12

4.6 Individual Response Analysis
Individual response analysis revealed that 11 out of 12 participants (91.7%) in the experimental group achieved clinically meaningful improvements (>20%) in hip eccentric strength at 60°/s, compared to 3 out of 12 participants (25.0%) in the control group. For suplex success rate, 10 out of 12 participants (83.3%) in the experimental group achieved meaningful improvements compared to 4 out of 12 participants (33.3%) in the control group.

5. Discussion
5.1 Primary Findings
This study demonstrates that 10 weeks of iso-inertial flywheel training significantly improves hip eccentric strength and suplex technique performance in senior Greco-Roman wrestlers. The experimental group showed superior improvements across all measured variables compared to the control group, with effect sizes ranging from large to very large, indicating both statistical significance and substantial practical importance.

The 28.5% improvement in hip eccentric strength at 60°/s and 31.2% improvement at 180°/s represent remarkable enhancements in a critical performance determinant for wrestling success. These findings exceed typical improvements reported in traditional strength training studies and suggest that the unique loading characteristics of flywheel training optimized eccentric strength adaptations (Maroto-Izquierdo *et al.*, 2017, p. 425) [15].

5.2 Mechanisms of Eccentric Strength Enhancement
The superior eccentric strength adaptations observed in the experimental group can be attributed to several unique characteristics of flywheel training:

Eccentric Overload Mechanism: The flywheel device's ability to store kinetic energy during the concentric phase and release it during the eccentric phase creates an overload situation where eccentric forces exceed concentric forces by 1.3-1.8 times (Sabido *et al.*, 2017, p. 236) [19]. This eccentric emphasis directly targets the strength qualities most relevant to suplex technique execution.

Accommodating Resistance: Unlike traditional weight training with constant external load, flywheel training provides accommodating resistance that matches the force-velocity characteristics of human muscle (Núñez *et al.*, 2020, p. 180) [17]. This enables maximal muscle activation throughout the entire range of motion, potentially optimizing training adaptations.

Neuromuscular Adaptations: The variable and unpredictable nature of flywheel resistance requires enhanced neuromuscular control and motor unit recruitment patterns (Todos-Fajardo *et al.*, 2016, p. 380) [22]. These neural adaptations likely contributed to the improved movement control and technique execution quality observed in the experimental group.

Specificity of Movement Patterns: The flywheel exercises closely mimicked the hip extension and flexion patterns required for suplex execution, ensuring high transfer of training adaptations to competitive performance contexts (Petré *et al.*, 2018, p. 347) [18].

5.3 Suplex Technique Performance Improvements
The dramatic improvements in suplex performance (36.3% increase in success rate, 30.9% improvement in execution quality) can be attributed to several interconnected factors:

Enhanced Eccentric Control: The significant improvements in hip eccentric strength directly translated to enhanced control during the critical landing phase of suplex techniques. The strong correlation between eccentric strength gains and landing control scores (r = 0.812) supports this relationship.

Improved Force Production Capacity: The enhanced strength capacity enabled wrestlers to generate the forces necessary for successful opponent lifting while maintaining sufficient reserve capacity for controlled technique completion.

Neuromuscular Coordination: The complex neuromuscular demands of flywheel training enhanced the coordination patterns required for effective suplex execution. The improvement in execution quality scores suggests that the training protocol enhanced both physical capacity and technical skill simultaneously.

Confidence and Technique Commitment: The enhanced eccentric strength capacity likely increased wrestlers' confidence in their ability to safely execute suplex techniques, leading to more committed and successful technique attempts.

5.4 Comparison with Previous Research

The eccentric strength improvements observed in this study exceed those reported in most previous flywheel training research. Vicens-Bordas *et al*. (2018, p. 458) [24] reported 24% improvements in eccentric hamstring strength following flywheel training, while the current study achieved 28.5-31.2% improvements in hip eccentric strength. This superior adaptation may be attributed to the wrestling-specific exercise selection and the previously untrained nature of eccentric strength in this population.

The technical performance improvements also exceed those typically reported in wrestling training studies. Hussein and Jaafar (2021, p. 236) [6] found 18% improvements in throwing technique success rates following traditional strength training, compared to the 36.3% improvement observed in the current study. This suggests that the eccentric emphasis of flywheel training produces superior transfer to wrestling performance.

The correlation strengths between strength and performance measures (r = 0.793 for eccentric strength and success rate) support previous findings by Al-Rubaie and Al-Kaabi (2022, p. 136) [1] and provide strong evidence for the importance of eccentric strength in wrestling technique execution.

5.5 Practical Applications and Implementation

The results of this study have several important implications for wrestling training and coaching practice:

Training Program Integration: Coaches should consider incorporating flywheel training into their strength training programs, particularly for wrestlers specializing in high-amplitude throwing techniques. The protocol can be effectively integrated during specific preparation phases when technique refinement is prioritized.

Equipment Considerations: The compact and portable nature of flywheel devices makes them suitable for implementation in various training environments. This accessibility is particularly valuable for wrestling programs seeking to enhance eccentric strength training capabilities.

Periodization Applications: The 10-week intervention period with progressive inertial loading provides a practical framework for implementation. The phase-based progression allows for systematic adaptation while maintaining high training loads throughout the intervention.

Safety Benefits: The enhanced eccentric strength and landing control observed in this study have important safety implications for high-risk wrestling techniques. Improved eccentric strength capacity may reduce injury risk during technique execution.

5.6 Limitations and Considerations

Several limitations should be considered when interpreting and applying these results:

Sample Characteristics: The study included only senior male Greco-Roman wrestlers from a specific geographic region. The effectiveness of flywheel training may vary in different populations, including female wrestlers, younger athletes, or freestyle wrestlers.

Training Experience: All participants were experienced wrestlers but had no previous flywheel training experience. The novelty of the training stimulus may have contributed to the observed improvements, and responses may differ in flywheel-trained athletes.

Control Group Design: While the control group followed traditional strength training methods, comparison with other evidence-based training approaches would provide additional insights into the relative effectiveness of flywheel training.

Technique Specificity: The study focused specifically on suplex techniques. The transfer of flywheel training benefits to other wrestling techniques requires further investigation.

5.7 Future Research Directions

Based on the findings of this study, several areas warrant further investigation:

Dose-Response Relationships: Research examining different flywheel training parameters (inertial loads, volume, frequency) would help optimize training prescription for different populations and competitive levels.

Long-term Adaptations: Studies investigating the sustainability of flywheel training adaptations and optimal maintenance strategies would inform long-term periodization planning.

Injury Prevention: Research examining the injury prevention benefits of enhanced eccentric strength through flywheel training would strengthen the practical relevance of this training method.

Technique Transfer: Investigation of flywheel training effects on other wrestling techniques requiring eccentric strength would expand the applicability of these findings.

Gender and Age Differences: Studies examining flywheel training responses in female wrestlers and different age groups would broaden the evidence base for this training method.

6. Conclusion

This study provides compelling evidence that iso-inertial flywheel training is a highly effective method for improving hip eccentric strength and suplex technique performance in senior Greco-Roman wrestlers. The 10-week intervention produced significant improvements in all measured variables, with the experimental group demonstrating superior adaptations compared to the control group across multiple performance domains.

Key findings include

1. Substantial enhancement of hip eccentric strength (28.5% increase at 60°/s, 31.2% increase at 180°/s), indicating remarkable improvements in a critical strength quality for wrestling performance
2. Dramatic improvement in suplex technique success (36.3% increase in success rate), representing the primary technical outcome of interest
3. Enhanced execution quality and safety (30.9% improvement in execution quality, 29.6% improvement in landing control), demonstrating both performance and safety benefits
4. Strong correlation between strength and performance gains (r = 0.793), providing evidence for the mechanistic relationship between eccentric strength and technique success
5. Superior individual response rates (91.7% achieving meaningful strength improvements), indicating robust effectiveness across diverse athlete populations

The exceptionally strong correlations between eccentric strength improvements and technical performance enhancements provide compelling evidence that flywheel training creates specific adaptations that directly benefit wrestling technique execution. This finding supports the principle of training specificity and demonstrates the importance of eccentric strength development for complex wrestling techniques.

The practical significance of these results extends beyond laboratory measurements to real-world wrestling performance. The improved eccentric strength and enhanced suplex technique execution represent fundamental capabilities that directly influence competitive success and athlete safety. The accessibility and versatility of flywheel training make this protocol suitable for implementation across diverse wrestling programs.

The novel application of iso-inertial flywheel training to wrestling-specific strength development represents a significant advancement in combat sports training methodology. This approach addresses the critical need for training methods that specifically target eccentric strength while maintaining high transfer to competitive performance contexts.

The high individual response rate and large effect sizes demonstrate the robust effectiveness of this training approach, making it a valuable addition to evidence-based wrestling training programs. Future research should continue to explore the applications of flywheel training in various wrestling populations and techniques, with particular attention to long-term adaptations, injury prevention benefits, and optimal training parameters.

The implications of this research extend beyond Greco-Roman wrestling to other combat sports requiring similar strength qualities and technique characteristics. The principles of eccentric strength development through flywheel training may be successfully adapted to various athletic contexts requiring controlled force production and movement quality.

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Conflict of Interest Statement

The authors declare no conflicts of interest regarding the publication of this article.

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Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request, in accordance with the University of Kirkuk Research Ethics Committee guidelines.

Appendices

Appendix A: Iso-inertial Flywheel Training Protocol

Phase 1: Familiarization (Weeks 1-2)

- **Objective:** Learn proper technique and movement patterns
- **Volume:** 3 sets × 8 repetitions
- **Inertial Load:** 0.025 kg·m² (low resistance)
- **Rest Intervals:** 2-3 minutes between sets
- **Focus:** Movement quality, technique mastery, safety protocols

Phase 2: Development (Weeks 3-4)

- **Objective:** Increase force production and loading
- **Volume:** 4 sets × 6 repetitions
- **Inertial Load:** 0.050 kg·m² (moderate resistance)
- **Rest Intervals:** 2-3 minutes between sets
- **Focus:** Progressive overload, eccentric emphasis

Phase 3: Intensification (Weeks 5-7)

- **Objective:** Maximize eccentric overload adaptations
- **Volume:** 4 sets × 6 repetitions
- **Inertial Load:** 0.075 kg·m² (high resistance)
- **Rest Intervals:** 3-4 minutes between sets
- **Focus:** Maximal eccentric force production

Phase 4: Peaking (Weeks 8-10)

- **Objective:** Optimize power expression and technique integration
- **Volume:** 3 sets × 8 repetitions
- **Inertial Load:** 0.050 kg·m² (moderate resistance)
- **Rest Intervals:** 2-3 minutes between sets
- **Focus:** Power development, wrestling-specific applications

Appendix B: Suplex Technique Assessment Protocol

Standardized Assessment Conditions:

- **Wrestling mat:** International standard 12m × 12m competition mat
- **Training partner:** Similar weight category, experienced wrestler
- **Assessment time:** Consistent timing (10:00 AM - 12:00 PM)
- **Warm-up protocol:** 20 minutes standardized preparation
- **Recovery between attempts:** 45 seconds minimum
- **Environmental conditions:** Temperature 22-24°C, humidity 45-55%

Success Criteria for Suplex Technique:

1. **Proper Setup:** Correct grip establishment and body positioning

2. **Lifting Phase:** Successful elevation of opponent to overhead position
3. **Arching Motion:** Controlled backward throw with proper form
4. **Landing Control:** Safe and controlled descent for both wrestlers
5. **Point Scoring:** Technique meets competition scoring requirements

Quality Assessment Rubric (10-point scale)

- **Technical Setup (2 points):** Grip, stance, timing, approach angle
- **Lifting Execution (3 points):** Power, height achieved, control maintenance
- **Throwing Motion (3 points):** Arc quality, body position, technique flow
- **Landing Safety (2 points):** Controlled descent, safe completion, positioning

Biomechanical Analysis Parameters

- **Force Plates:** Ground reaction forces during lifting and landing phases
- **Motion Capture:** 3D kinematics using 8-camera system (200 Hz)
- **EMG Analysis:** Muscle activation patterns in key muscle groups
- **High-Speed Video:** 1000 fps recording from multiple angles

Appendix C: Hip Eccentric Strength Testing Protocol
Biodex System 4 Isokinetic Testing Protocol
Equipment Setup

- Biodex System 4 Pro isokinetic dynamometer
- Hip attachment with dual-axis positioning
- Safety restraint system and emergency stop
- Real-time visual feedback display

Subject Positioning

- **Position:** Supine lying with hip at 90° flexion
- **Stabilization:** Chest and pelvic straps, contralateral leg secured
- **Axis Alignment:** Hip joint axis aligned with dynamometer axis
- **Range of Motion:** 90° hip flexion to 0° (neutral position)

Testing Protocol

1. **Warm-up:** 5 submaximal contractions at each test speed
2. **Familiarization:** 3 practice repetitions at 50% effort
3. **Testing Speeds:** 60°/s and 180°/s (randomized order)
4. **Repetitions:** 5 maximal efforts at each speed
5. **Rest:** 2 minutes between speeds, 30 seconds between repetitions
6. **Instructions:** "Push as hard as possible during the lowering phase"

Outcome Measures

- **Peak Torque (Nm):** Maximum eccentric torque achieved
- **Total Work (J):** Total work performed during eccentric phase
- **Average Power (W):** Mean power output during eccentric contraction
- **Eccentric:Concentric Ratio:** Functional strength balance assessment

Quality Control

- Coefficient of variation < 10% for test-retest reliability
- Visual feedback to ensure maximal effort
- Standardized verbal encouragement
- Gravity correction for limb weight

Appendix D: Participant Screening and Consent Questionnaire
Participant Screening Questionnaire *Iso-inertial Flywheel Training Study in Greco-Roman Wrestling*

Principal Investigator: Dr. Fariq Faiq Qasim

Institution: University of Kirkuk, College of Physical Education and Sports Sciences

Study Reference: UoK/CPES/2023/089
Date: ________________

Section A: Personal Information
1. Participant Details

- Full Name: ____
- Date of Birth: //_______ (DD/MM/YYYY)
- Age: _______ years
- Nationality: ______________________________________
- Address: ____
- Mobile Phone: ____________________________________
- Email: ____
- Emergency Contact: ________________________________
- Emergency Phone: __________________________________

2. Physical Characteristics

- Height: _______ cm
- Current Weight: _______ kg
- Competition Weight: _______ kg
- Weight Category: _______ kg division
- Body Fat % (if known): _______ %
- Dominant Side: □ Right □ Left

Section B: Wrestling Background
3. Wrestling Experience

- Total years of wrestling: _______ years
- Years in Greco-Roman style: _______ years
- Age when started wrestling: _______ years
- Current wrestling club: ____________________________
- Head coach name: __________________________________
- Assistant coach: ___________________________________

4. Training Schedule

- Training sessions per week: _______ sessions
- Hours per training session: _______ hours
- Strength training sessions per week: _______ sessions

- Technical training sessions per week: _______ sessions
- Rest days per week: _______ days

5. Competition Experience *(Check all that apply)* □ Club level competitions □ City/Regional championships □ National championships □ International tournaments □ Asian championships □ World championships □ Olympic competitions □ University competitions

6. Recent Competition Results *(Last 12 months)*

- Best achievement: ________________________________
- Number of competitions: _______ events
- Win percentage: _______ %
- Current national ranking: __________________________

7. Suplex Technique Proficiency

- Years practicing suplex: _______ years
- Rate your suplex skill (1-10): _______ /10
- Success rate in training: _______ %
- Success rate in competition: _______ %
- Favorite suplex variations: _________________________

Section C: Health and Medical History

8. General Health Assessment

- Overall health status: □ Excellent □ Good □ Fair □ Poor
- Any chronic medical conditions? □ Yes □ No If yes, specify: ________________________________
- Currently taking medications? □ Yes □ No If yes, list: _________________________________
- Known allergies: ________________________________

9. Cardiovascular Health

- Resting heart rate: _______ bpm (if known)
- Blood pressure: / mmHg (if known)
- Any heart problems? □ Yes □ No
- Chest pain during exercise? □ Yes □ No
- Shortness of breath? □ Yes □ No
- Dizziness during training? □ Yes □ No
- Family history of heart disease? □ Yes □ No

10. Musculoskeletal Health

- Any current pain or discomfort? □ Yes □ No Location and severity (1-10): ______________________
- Previous surgeries? □ Yes □ No Details: ______________________________________
- Bone fractures? □ Yes □ No When and where: ________________________________

11. Hip and Lower Back Health *(Critical for study participation)*

- Hip pain in last 18 months? □ Yes □ No
- Lower back pain? □ Yes □ No
- Hip flexibility limitations? □ Yes □ No
- Previous hip injuries? □ Yes □ No Details: ______________________________________
- Previous lower back injuries? □ Yes □ No Details: ______________________________________

12. Wrestling-Specific Injuries *(Check all that have occurred)* □ Concussion/head trauma □ Neck injury □ Shoulder dislocation/separation □ Elbow injury □ Wrist/hand injury □ Rib injury □ Hip injury/strain □ Knee injury (ligament/meniscus) □ Ankle sprain □ Muscle tears/strains □ Back injury □ None of the above

13. Injury History Timeline Most recent significant injury:

- Type: ____
- Date: ____
- Treatment received: ______________________________
- Full recovery? □ Yes □ No
- Any ongoing effects? □ Yes □ No

Section D: Training and Performance

14. Current Strength Training

- Years of strength training: _______ years
- Primary training methods: ____________________________
- Squat 1RM (if known): _______ kg
- Deadlift 1RM (if known): _______ kg
- Bench press 1RM (if known): _______ kg

15. Previous Flywheel Training Experience □ No experience with flywheel devices □ Seen flywheel training but never participated □ Limited experience (< 4 weeks) □ Moderate experience (1-6 months) □ Extensive experience (> 6 months)

16. Eccentric Training Background

- Familiar with eccentric training? □ Yes □ No
- Previous eccentric training programs? □ Yes □ No
- Nordic hamstring curls experience? □ Yes □ No
- Negative/eccentric bench press? □ Yes □ No

17. Performance Goals

- Primary performance goal: ___________________________
- Strength development priority: _________________________
- Technical improvement focus: _________________________
- Competition preparation timeline: ______________________

Section E: Lifestyle Factors

18. Sleep and Recovery

- Average sleep duration: _______ hours per night
- Sleep quality (1-10): _______ /10
- Regular sleep schedule? □ Yes □ No
- Use of sleep aids? □ Yes □ No

19. Nutrition and Hydration

- Follow specific diet plan? □ Yes □ No
- Dietary restrictions: ________________________________
- Supplement use: ________________________________
- Daily water intake: _______ liters
- Pre-training meal timing: _______ hours before

20. Lifestyle Habits

- Smoking status: □ Never □ Former □ Current
- Alcohol consumption: □ Never □ Occasional □ Regular
- Stress level (1-10): _______ /10
- Other sports participation: ____________________________

Section F: Study-Specific Information

21. Study Understanding

- How did you learn about this study? ______________________
- Understanding of study purpose (1-10): _______ /10
- Concerns about participation: __________________________
- Questions about procedures: ___________________________

22. Availability and Commitment

- Available for full 12-week duration? □ Yes □ No
- Can attend 3 sessions per week? □ Yes □ No
- Available for pre/post testing? □ Yes □ No
- Planned absences during study: _________________________

23. Motivation Level

- Interest in flywheel training (1-10): _______ /10
- Motivation to complete study (1-10): _______ /10
- Expected benefits from participation: ______________________
- Willingness to follow protocols strictly: □ Yes □ No

24. Support System

- Coach support for participation? □ Yes □ No
- Family support? □ Yes □ No
- Training partner availability? □ Yes □ No
- Transportation to sessions? □ Yes □ No

Section G: Technical Assessment

25. Suplex Technique Evaluation (To be completed by coach)

- **Technical proficiency (1-10): _______** /10
- **Consistency of execution:** □ Excellent □ Good □ Fair □ Poor
- **Power in lifting phase:** □ Excellent □ Good □ Fair □ Poor
- **Control in landing:** □ Excellent □ Good □ Fair □ Poor
- **Safety awareness:** □ Excellent □ Good □ Fair □ Poor

26. Strength Assessment Readiness

- Familiar with isokinetic testing? □ Yes □ No
- Previous dynamometer experience? □ Yes □ No
- Comfortable with maximal testing? □ Yes □ No
- Any concerns about strength testing? ______________________

Section H: Consent and Agreements

27. Informed Consent (Check each box after reading) □ I have read and understood the participant information sheet □ I understand the study procedures and requirements □ I understand the potential risks and benefits □ I understand that participation is voluntary □ I can withdraw at any time without penalty □ I consent to video recording for analysis □ I agree to follow all safety protocols □ I will report any injuries or concerns immediately

28. Data and Privacy □ I consent to collection and use of my data for research □ I understand data storage and confidentiality procedures □ I consent to anonymous publication of results □ I understand my right to access my data □ I consent to photography for technique analysis □ I agree to maintain confidentiality about study procedures

29. Medical and Safety □ I have medical clearance for high-intensity exercise □ I will inform researchers of any health changes □ I understand the importance of following safety protocols □ I agree to use all provided safety equipment □ I will not train with other equipment during the study period

30. Commitment Agreement □ I commit to attending all scheduled sessions □ I will maintain my current diet and sleep patterns □ I will not begin new training programs during the study □ I will complete all required assessments □ I understand the importance of consistent participation

Section I: Additional Information

31. Coach Evaluation (To be completed by head coach)

- **Athlete's dedication level:** □ High □ Medium □ Low
- **Technical coachability:** □ Excellent □ Good □ Fair □ Poor
- **Physical preparation:** □ Excellent □ Good □ Fair □ Poor
- **Injury risk assessment:** □ Low □ Medium □ High
- **Recommendation for study:** □ Strongly support □ Support □ Neutral □ Do not support

32. Referee/Contact Verification

- Reference name: ____________________________
- Relationship to participant: _______________________
- Contact phone: ____________________________
- Email: __________________________________
- Years of knowing participant: _______ years

33. Additional Comments Use this space for any additional information relevant to your participation:

____
____
____
____
____

Declarations and Signatures

Participant Declaration: I declare that all information provided in this questionnaire is true and accurate to the best of my knowledge. I understand that providing false information may result in exclusion from the study.

Participant Signature: ______________________

Date: _________

Participant Name (Print): _____________________________

Parent/Guardian Signature (if under 18): __________________ **Date:** ___________

Parent/Guardian Name (Print): ______________________________________

Coach Verification: I verify that this athlete is technically proficient and physically prepared for participation in this study.

Coach Signature: _______________________________ **Date:** ___________

Coach Name (Print): ____

Researcher Signature: ___________________________ **Date:** ___________

Researcher Name (Print): ____

For Research Team Use Only
Screening Decision: □ Eligible for participation - proceed to randomization □ Eligible with conditions: __________________________________ □ Not eligible - **exclusion reason:** ______________________________ □ Requires medical clearance before participation □ Requires additional information: _______________________________

Group Assignment: □ Experimental Group (Flywheel Training) □ Control Group (Traditional Training)

Baseline Testing Schedule

- Strength testing date: _____________________________________
- Technical assessment date: ________________________________
- Training start date: _______________________________________

Study Identification

- Participant ID: ____
- Randomization number: _________________________________
- Group assignment code: __________________________________

Screening Completed by: _______________________ **Date:** ___________

Medical Clearance: □ Approved □ Pending □ Required

Final Approval by PI: ___________________________ **Date:** ___________