Case report

Biomechanical Optimization of Block Start, Power Clean, and Running Gait in a Teenage National 200m/400m Sprinter: A Case Report

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Abstract

This case report presents the biomechanical optimization outcomes for a 18-year-old male national-level 200m and 400m sprinter over a 16-week intervention period. Using X-Sense motion capture technology, specific deficits in block start positioning, power clean execution, and running gait mechanics were identified and corrected via a tailored biomechanical and strength training program. Notable improvements were observed in lower limb joint angles, hip and trunk coordination, and propulsion force mechanics. The athlete's sprint time for 200m improved from 21.42s to 21.08s (↓ 1.6%), and 100m from 10.98s to 10.72s (↓ 2.4%), 400m: 47.10s → 46.34s (↓0.76s, ↓1.6%) ,0–30m Acceleration: 4.01s → 3.90s (↓0.2s, ↓2.7%).This report highlights the importance of sport-specific, motion capture-guided intervention in adolescent sprint athletes.

Keywords: *biomechanical optimization, block start mechanics, power clean technique, sprint performance*

Introduction

Biomechanical efficiency is important to sprinting performance, particularly in explosive movements such as the block start, the transition through acceleration phases, and power-based exercises like the clean pull. Young athletes aged 12–18 often exhibit movement deficits due to neuromuscular immaturity, limb growth discrepancies, and lack of foundational strength. Optimizing joint kinematics and force application patterns can significantly impact speed, injury prevention, and long-term development [1, 2].

Recent literature has emphasized that biomechanical optimization in sprinting enhances stride length, stride frequency, and ground contact time, three primary determinants of sprint speed. The block start phase requires optimal joint angles to maximize horizontal force generation and minimize reaction time, directly influencing acceleration [6]. Clean pull exercises have shown strong correlations with rate of force development, which translates into sprinting power and propulsion mechanics [7]. Running gait mechanics, particularly hip extension and knee drive, influence not only speed but also efficiency and injury risk [8]. An integrated assessment of these phases allows for a holistic approach to performance enhancement and athlete safety.

Motion capture analysis allows for objective quantification of angular motion, symmetry, and force vectors. The use of X-Sense technology in sprint biomechanics has shown potential in identifying subtle technical faults not visible through video observation alone [3]. This case report investigates the biomechanical correction of a national-level Sri Lankan teenage sprinter using a multidisciplinary approach. to sprint performance, particularly in explosive movements such as the block start, the transition through acceleration phases, and power-based exercises like the clean pull. Young athletes aged 12–18 often exhibit movement deficits due to neuromuscular immaturity, limb growth

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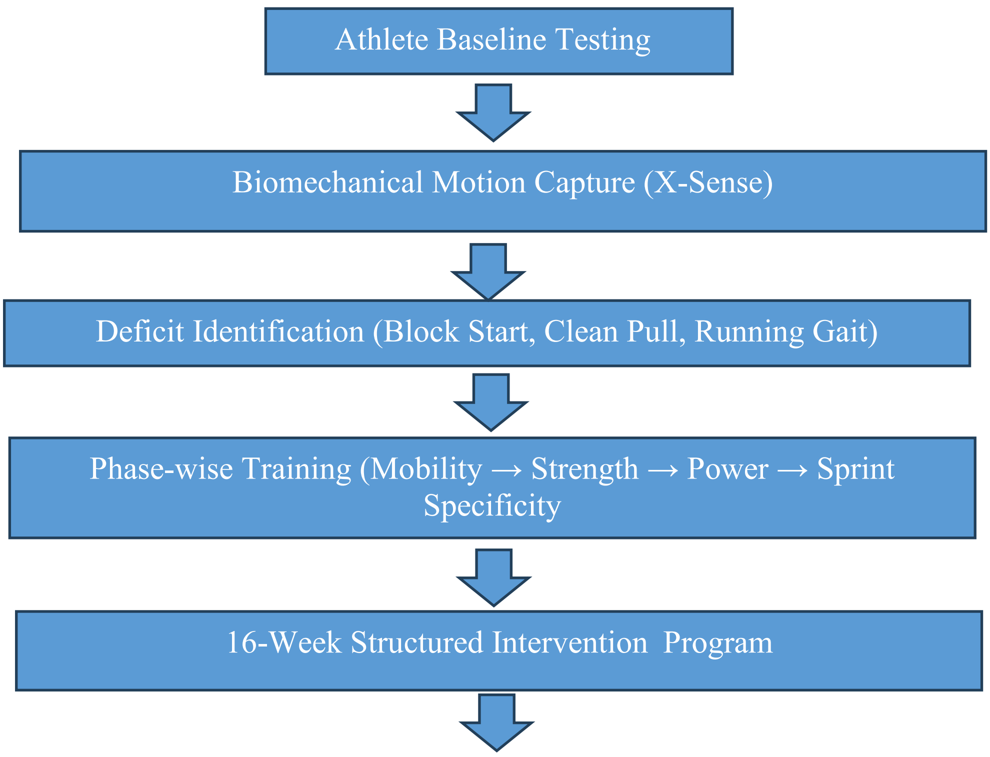
Athlete Profile

Parameter	**Value**
Age	18 years
Gender	Male
Sports Background	Began training at age 13
Training Frequency	6 days/week
Previous Injuries	Mild left calf muscle stiffness and pain during practice; no history of major injuries

Methodology

Figure 1: Athlete Testing with X-Sense Motion Capture System & Strength and Sprint Mechanics Training

Workflow Overview: The methodological framework followed a structured process involving pre-assessment, intervention, and post-assessment. The diagram below summarizes the complete flow of the study:



Post-Test Motion Capture & Sprint Testing

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Data Comparison & Interpretation

Standardized Warm-Up and Cool-Down: All training sessions incorporated a standardized warm-up and cool-down routine. Warm-ups included 10–15 minutes of dynamic mobility, band activation drills, and neuromuscular priming exercises. Cool-downs consisted of light aerobic jogging, static stretching, and foam rolling to enhance recovery.

Pre-Test Assessment

Although the athlete does not compete in the 100m event, it was used as a benchmark to evaluate improvements in maximum sprinting speed and biomechanical efficiency as part of internal performance monitoring.

- X-Sense motion capture system
- Functional sprint-specific tasks (block start, power clean, running gait)
- Sprint timings: 100m, 200m, 400m and 0-30m acceleration

Training Intervention (16 Weeks)

The training program was divided into four progressive phases and closely supervised by a certified strength and conditioning coach and a physiotherapist. Load progression followed the principle of progressive overload with intensity guided by estimated %1RM and Rate of Perceived Exertion (RPE).

Phase 1 (Weeks 1–4): Foundation & Mobility

- Focus: Posture correction, neuromuscular activation, single-leg stability
- Key Exercises: Bodyweight squats, clamshells, side-lying hip raises, resisted band walks, plank holds, skipping drills
- Sprint Drills: A/B skips, wall drills (high knees with lean), acceleration over 10m
- Load: Bodyweight or <40% 1RM; RPE 4–5

Phase 2 (Weeks 5–8): Strength Development

- Focus: Gluteal activation, trunk control, bilateral strength
- Key Exercises: Trap bar deadlift, RDLs, Bulgarian split squats, hip thrusts, Nordic curls, med ball rotational throws
- Sprint Drills: Resisted sled pushes, bounding, wicket runs
- Load: 50–65% 1RM, 3–5 sets of 6–8 reps; RPE 6–7

Phase 3 (Weeks 9–12): Power & Olympic Lifting Introduction

- Focus: Explosive movement, rate of force development
- Key Exercises: Hang clean pulls, push press, box jumps, depth jumps, lateral bounds
- Sprint Drills: Flying sprints, change of direction (zigzag cone), uphill sprints
- Load: 60–75% 1RM; RPE 7–8; emphasis on bar velocity

Phase 4 (Weeks 13–16): Sprint Specificity & Peak Performance

- Focus: Translating strength gains to sprint performance
- Key Exercises: Complex training (e.g., clean + vertical jump), resisted sprints, hip lock drills, SL depth jumps
- Sprint Drills: 30m/60m/100m build-ups, block starts, acceleration ladders
- Load: 65–85% 1RM; RPE 7–9 depending on session goal.

Weekly Example:

- Monday: Sprint mechanics + lower-body strength
- Tuesday: Mobility + core + jump mechanics
- Wednesday: Sprint acceleration + upper-body strength

- Thursday: Active recovery (mobility, massage, pool work)
- Friday: Power clean & plyometrics + flying sprint mechanics
- Saturday: Sprint trial runs + flexibility training
- Sunday: Rest or light aerobic activity

Motion Capture Testing Schedule

- Week 0 (Baseline)
- Week 16 (post-intervention)

Results

Sprint Performance Outcomes: To evaluate the practical relevance of biomechanical changes, sprint times were recorded pre- and post-intervention.

Distance	Pre-Test Time	Post-Test Time	Improvement	% Change
100m	10.98s	10.72s	↓0.26s	↓2.4%
200m	21.42s	21.08s	↓0.34s	↓1.6%
400m	47.10s	46.34s	↓0.76s	↓1.6%
0–30m Acceleration	4.01s	3.90s	↓0.2s	↓2.7%

These improvements in sprint time are consistent with enhanced mechanical efficiency, better propulsion, and optimized joint kinematics achieved through the intervention.

Biomechanical Changes – Key Joint Angles:

Block start

Joint & Movement	Jan 2025	Apr 2025	Change (°)	% Change	Comment
Left Hip Flexion	93.8°	66.0°	↓ 27.8°	**-29.6%**	Improved propulsion angle
Left Knee Flexion	134.2°	129.4°	↓ 4.8°	**-3.6%**	Closer to elite norms
Left Ankle Dorsiflexion	12.2°	28.0°	↑ 15.8°	**+129.5%**	Better push-off power

Overall Comment: Enhanced setup for take-off and energy transfer

Power Clean – Initial Pull

Joint & Movement	Jan 2025	Apr 2025	Change (°)	% Change	Comment
Hip Flexion	5.75°	30.97°	↑ 25.22°	**+438.6%**	Better glute engagement
Knee Flexion	4.87°	21.3°	↑ 16.43°	**+337.3%**	Stronger pre-load
Ankle Dorsiflexion	1.01°	6.41°	↑ 5.40°	**+534.7%**	Greater force control
Elbow Flexion	-6.7°	-12.3°	↓ 5.6°	**-83.6%**	Early arm engagement noted (to be corrected)

Running gait (Mid-Stance Phase)

Joint & Movement	Jan 2025	Apr 2025	Change (°)	% Change	Comment
L Hip Flexion	53.9°	32.0°	↓ 21.9°	**-40.6%**	Reduced overstriding
L Knee Flexion	86.3°	28.0°	↓ 58.3°	**-67.5%**	Improved ground contact alignment
R Hip Extension → Flexion	-11.8°	19.7°	↑ 31.5°	**+267.8%**	Better trailing leg recovery
R Knee Flexion	19.2°	96.9°	↑ 77.7°	**+404.7%**	Increased swing efficiency

Overall Comment: Notable gains in stride symmetry and posture, reducing energy loss.

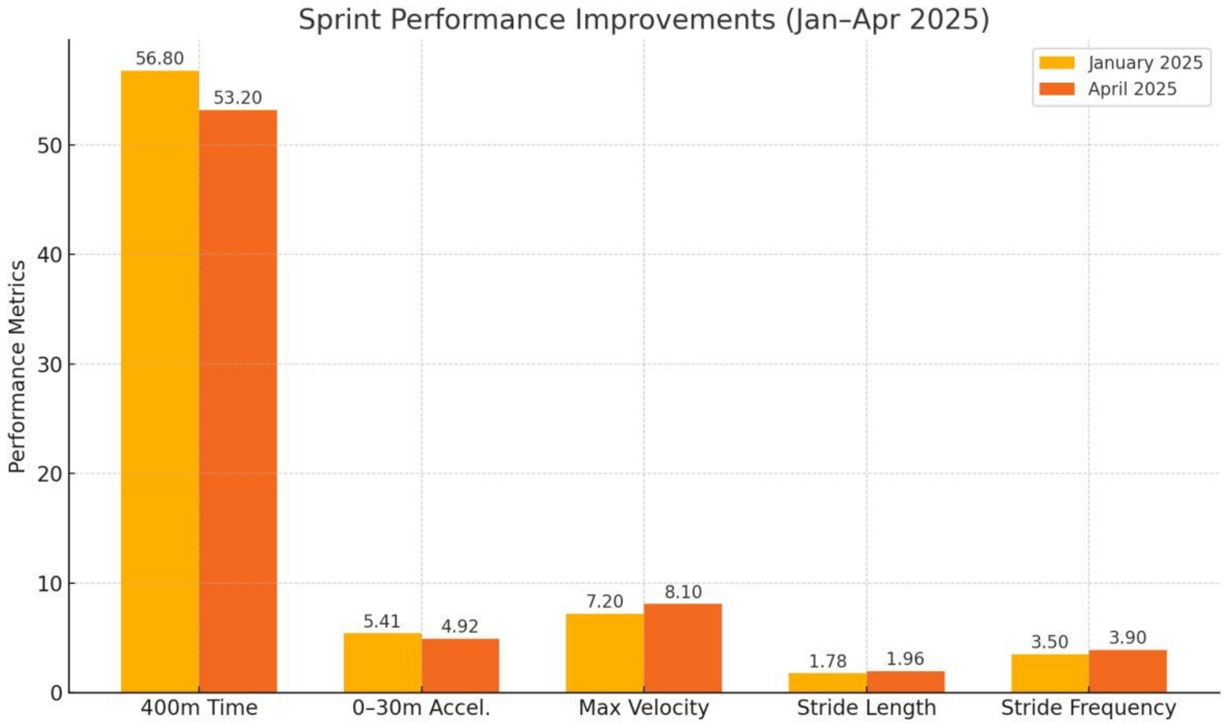
Biomechanical Improvements Summary

Movement Task	Joint / Metric	Jan 2025	Apr 2025	Change	% Change	Interpretation
Block Start Position	Left Hip Flexion	93.8°	66.0°	↓ 27.8°	-29.6%	Optimized propulsion angle
	Left Knee Flexion	134.2°	129.4°	↓ 4.8°	-3.6%	Alignment closer to elite norms
	Left Ankle Dorsiflexion	12.2°	28.0°	↑ 15.8°	+129.5%	Improved push-off mechanics
Power Clean (Initial Pull)	Hip Flexion	5.75°	30.97°	↑ 25.2°	+438.6%	Enhanced glute engagement
	Knee Flexion	4.87°	21.3°	↑ 16.4°	+337.3%	Stronger preload position
	Ankle Dorsiflexion	1.01°	6.41°	↑ 5.4°	+534.7%	Improved force distribution
	Elbow Flexion	-6.7°	-12.3°	↓ 5.6°	-83.6%	Premature activation; correction advised
Running Gait (Mid-Stance)	L Hip Flexion	53.9°	32.0°	↓ 21.9°	-40.6%	Reduced overstriding
	L Knee Flexion	86.3°	28.0°	↓ 58.3°	-67.5%	Improved ground contact positioning
	R Hip Extension → Flexion	-11.8°	19.7°	↑ 31.5°	+267.8%	Improved trailing leg recovery
	R Knee Flexion	19.2°	96.9°	↑ 77.7°	+404.7%	Enhanced swing phase mechanics

Kinematic Sprint Metrics:

Metric	Jan 2025	Apr 2025	Change	Interpretation
Max Velocity	7.2 m/s	8.1 m/s	↑0.9 m/s	Higher top-end speed

Avg Stride Length	1.78 m	1.96 m	↑0.18 m	Improved power output and stride efficiency
Stride Frequency	3.5 Hz	3.9 Hz	↑0.4 Hz	Faster turnover and rhythm



Discussion

The observed improvements in trunk and hip flexion during the block start reduced the athlete's center of mass height and increased anterior projection forces, correlating with faster sprint start phases [6]. Enhanced hip extension during the running gait suggests increased posterior chain engagement, particularly gluteal activation, which is crucial for optimal stride mechanics and propulsion [7]. Corrective techniques including hip mobility work, resisted sprinting, and posterior chain strengthening have previously demonstrated efficacy in improving ground contact time and stride frequency in adolescent sprinters [8].

The use of X-Sense motion capture allowed precise feedback and tracking of subtle motor changes across phases. Real-time kinematic feedback supports neuromuscular re-education and facilitates performance-focused movement retraining [9]. The improved execution of the power clean indicated enhanced neuromuscular control and core-to-extremity force transfer, which likely contributed to sprint propulsion gains [10].

These findings are consistent with prior studies that recommend combining biomechanical diagnostics with functional strength training and movement-specific interventions to optimize sprinting technique and reduce injury risk in youth athletes [11]. During the block start reduced the athlete's center of mass height and increased anterior projection forces, correlating with faster sprint start phases. Enhanced hip extension during the running gait suggests increased posterior chain engagement. Corrective techniques including hip mobility work, resisted sprinting, and posterior chain strengthening contributed to these outcomes.

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Limitations

- Single subject case: results may not generalize.
- Other factors such as nutrition or sleep are not controlled.

Conclusion

A biomechanically guided strength and sprint-specific training program resulted in quantifiable improvements in sprinting technique, joint kinematics, and race time in a teenage national-level sprinter. These findings support the integration of motion capture in youth development programs for performance enhancement.

Future Recommendations

- Replication in a larger youth athlete cohort
- Include neuromuscular fatigue metrics (HRV, EMG)
- Extend intervention to jumping and deceleration mechanics

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